A mining research contract report
September 1982

DEMONSTRATION OF NOISE CONTROL TECHNIQUES FOR THE CRUSHING AND SCREENING OF NONMETALLIC MINERALS

Bureau of Mines Open File Report 50-83

Contract No. J0100038
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. BuMines OFR 50-83	2.	3. Recipient's Accession No.

4. Title and Subtitle

Demonstration of Noise Control Techniques for the Crushing and Screening of Nonmetallic Minerals

5. Report Date Dec. 1981

6.

7. Author(s)

Robert J. Pokora and Terry L. Muldoon

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Foster-Miller Associates, Inc.
350 2d Ave.
Waltham, MA 02254

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)
(G) J0100038

12. Sponsoring Organization Name and Address

Office of Assistant Director--Mining Research
Bureau of Mines
U.S. Department of the Interior
Washington, D. C. 20241

13. Type of Report & Period Covered

Contract research, 2/80--12/81

14.

15. Supplementary Notes

Approved for release February 7, 1983.

16. Abstract (Limit: 200 words)

This report presents the details of a survey of the nonmetallic mining industry, the design and installation of retrofit noise control treatments for three crushing and screening plants, and the field evaluation of those controls under actual operating conditions.

17. Document Analysis a. Descriptors

Mining Research
Noise Control
Crushing and screening
Nonmetal mines

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group 08I

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited by NTIS.	Unclassified	187
	20. Security Class (This Page)	22. Price
	Unclassified	

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

FOREWORD

This report was prepared by Foster-Miller Associates, Inc. (FMA), of Waltham, MA, under USBM Contract No. J0100038. The contract was initiated under the Metal and Nonmetal Mine Health and Safety Research Program. It was administered under the technical direction of the Pittsburgh Research Center (PRC) with Mr. Thomas G. Bobick acting as Technical Project Officer. Mr. Howard Eveland was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period February 1980 to December 1981. This report was submitted by the authors on December 31, 1981.

The technical effort was performed by the Mining Division of the Engineering Systems Group under the supervision of Mr. David A. Monaghan. The Program Manager was Mr. Terry L. Muldoon. Mr. Robert J. Pokora and Mr. Kenneth Heller were directly responsible for the design, installation, and evaluation of the noise control treatments.

The cooperation of the *Wake Stone Coropration* and in particular the staff at its Moncure and Knightdale Quarries during the installation and evaluation of the retrofit noise control treatments is gratefully acknowledged. Special thanks are given to Mr. John Bratton, Jr., and Mr. John T. Bratton for their cooperation, assistance, and patience.

The assistance and input during the program from officials of the nonmetallic mineral industry and the USBM are gratefully acknowledged.

TABLE OF CONTENTS

Section		Page
	EXECUTIVE SUMMARY	14
ES.1	Plant B - Primary Jaw Crusher	20
ES.2	Plant B - Secondary Crushing and Screening Plant	20
ES.3	Plant A - Secondary Crushing and Screening Plant	
ES.4	Conclusions	37
1.	INTRODUCTION	38
1.1	Background	38
1.2	Objectives	39
1.3	Scope of Effort	40
2.	INDUSTRY SURVEY	42
2.1	Census of Nonmetallic Mining Industry	42
2.1.1	Crusher Statistics	43
2.1.2	Screen Statistics	47
2.1.3	Screening Media	47
2.1.4	Hoppers and Chutes	55
2.1.5	Typical Plant Layout	55
2.1.6	Portable Crushing and Screening Plants	57
2.1.7	Summary	57
2.2	Plant Selection and On-Site Visits	59
2.2.1	Plant Selection	59

TABLE OF CONTENTS (Continued)

Section		Page
2.2.2	Plant Surveys	62
2.3	Rank-Ordering of Surveyed Plants	67
2.3.1	Rank-Ordering by Noise Alone	67
2.3.2	Rank-Ordering by Multiple Objective Ranking Matrix	69
2.4	References	74
3.	RETROFIT NOISE CONTROL DESIGN	75
3.1	Final Site Selections	75
3.2	Preliminary Design	75
3.2.1	Plant B - Primary Crusher Installation	76
3.2.2	Plant B - Secondary Module	78
3.2.3	Plant A - Secondary Module	79
3.3	Follow-Up Plant Visits	79
3.3.1	Plant B - Primary Crusher Follow-Up Visit	80
3.3.2	Plant B - Inclined Screen Plant Follow-Up Visit	80
3.3.3	Plant A - Horizontal Screen Plant Follow-Up Visit	83
3.4	Retrofit Material Selection	83
3.5	Final Design, Fabrication, and Installation	89
3.5.1	Plant B - Primary Crusher	89

TABLE OF CONTENTS (Continued)

Section			Page
		3.5.2 Plant B - Inclined Screen/Cone Crusher Plant	94
		3.5.3 Plant A - Horizontal Screen/Cone Crusher Module	106
	3.6	Design and Installation Conclusions	115
4.		FIELD DEMONSTRATION RESULTS	117
	4.1	Portable Plant A - Noise Control Treatment Effectiveness	117
		4.1.1 Initial Treatment	117
		4.1.2 Modification 2	120
		4.1.3 Modification 3	124
		4.1.4 Followup Visits	124
		4.1.5 Plant A - Summary	130
	4.2	Portable Plant B - Noise Control Treatment Effectiveness	130
		4.2.1 Initial Treatment	133
		4.2.2 Modification 2	133
		4.2.3 Modification 3	138
		4.2.4 Followup Visits	138
		4.2.5 Summary	143
	4.3	Plant B - Primary Crusher Control Booth	143
	4.4	Plant A and Plant B Treatment Costs	145
5.		CONCLUSIONS AND RECOMMENDATIONS	149
	5.1	Conclusions	149

Proofer ____________ Typist ____________

TABLE OF CONTENTS (Continued)

Section		Page
5.2	Future Research Recommendations	149
5.2.1	Screening Efficiency	149
5.2.2	Wear Materials	150
5.2.3	New Portable Crushing and Screening Plants	150
APPENDIX A	DOSIMETER TEST RESULTS	151
APPENDIX B	PLANTS A THROUGH H: A-WEIGHTED NOISE LEVELS (dBA)	154
APPENDIX C	PLANT A AND PLANT B	161

LIST OF ILLUSTRATIONS

Figure		Page
ES-1	New primary crusher operator control booth being installed	21
ES-2	Inside the new primary crusher control booth during normal operation	22
ES-3	Plant B - inclined screen/cone crusher secondary portable plant	23
ES-4	Plant B - resilient screen discharge lip after processing 198,000 tons	25
ES-5	Plant B - resilient screen deck after processing 198,000 tons	26
ES-6	Plant B - crusher feed hopper liner after processing 198,000 tons	28
ES-7	Plant B - original resilient crusher feed plate showing premature wear around the mounting bolts	29
ES-8	Plant B - new resilient crusher feed plate being installed	30
ES-9	Plant B - noise control curtain installed around the crusher mainframe	31
ES-10	Plant A - horizontal screen/cone crusher secondary portable plant	32
ES-11	Plant A - resilient top screen deck after processing 191,000 tons	34
ES-12	Plant A - resilient crusher feed hopper liner after processing 480,000 tons	35
ES-13	Plant A - resilient bottom screen deck after processing 212,000 tons	36

Proofer

Typist

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
1.	Noise level versus permissible daily exposure	39
2.	Typical open circuit	56
3.	Typical closed circuit	58
4.	Potential attenuation points - portable crushing plant	77
5.	Control booth wall construction	91
6.	Operator's control booth	92
7.	Plant B - control booth at primary station	94
8.	Plant B - portable plant	95
9.	Plant B - screen feed end	96
10.	Plant B - screen panels and structural steel frames (shown inverted)	97
11.	Plant B - inclined screen and feed chute	98
12.	Rubber bumper blocks added to the screen side wings	99
13.	Rubber drag curtain used to retard material flow	100
14.	Plant B - crusher feed chute	101
15.	Plant B - crusher feed chute linings	102
16.	Plant B - crusher modifications	103
17.	Plant B - installing rubber crusher feed plate	104
18.	Curtain installed around the crusher main frame shell	105
19.	Plant A - portable plant	106

Proofer ______________ Typist ______________

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
20.	Plant A - screen feedchute	108
21.	Screen feedbox lining	109
22.	Plant A - horizontal screen retrofit	110
23.	Plant A - screen panels	111
24.	Screen panel with hold-down bolts and donuts	111
25.	Plant A - screen feed to secondary crusher	113
26.	Plant A - screen discharge lip	114
27.	Plant A - conical feed hopper lining segments	114
28.	Plant A - noise data base	118
29.	Effects of retrofit treatments at Plant A - position 6 - beside screen discharge	121
30.	Effects of retrofit treatments at Plant A - position 7 - beside screen feed end	122
31.	Effects of retrofit treatments at Plant A - position 5 - beside crusher feed	123
32.	Plant A - top deck screen panel	125
33.	Plant A - screen side protection	126
34.	Plant A - feed conveyor discharge box liner	127
35.	Plant A - screen feedbox liner	128
36.	Plant A - screen discharge lip	128
37.	Plant A - conical hopper liner	129
38.	Plant A - second screen deck cloth after 212,000 tons	129
39.	Plant B - noise data base	131

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
40.	Effects of retrofit treatments at Plant B - position 1 - beside screen	134
41.	Effects of retrofit treatments at Plant B - position no. 2 - screen discharge	135
42.	Effects of retrofit treatments at Plant B - position no. 5 - ground level screen pad	136
43.	Effects of retrofit treatments at Plant B - position no. 3 - ground level beside crusher	137
44.	Plant B screen area	139
45.	Plant B screen feed end	140
46.	Plant B screen cloth, typical condition	141
47.	Plant B screen discharge area	142
48.	Worn crusher feed plate - Plant B	142
49.	Plant B - crusher feed area	144
50.	Plant B - crusher noise curtain	144
51.	Plant B - primary crusher control booth	147

Proofer ______ Typist ______

LIST OF TABLES

Table		Page
ES-1	Plant survey data summary	16
ES-2	Plant noise levels, dBA	18
1.	Crusher population by crushing stages	44
2.	Crushers by type and manufacturer's market share	45
3.	Crushers by type and size distribution	46
4.	Screen statistics	48
5.	Relative popularity of screens by manufacturer	49
6.	Percent of screen population by sizes	50
7.	Relative importance of various buying motives in selection of screening media	51
8.	Percent of reporting plants using screening media types	52
9.	Percent of market by various manufacturers	53
10.	A sampling of plant reported annual tonnage and costs for woven wire cloth	54
11.	A sampling of plant reported annual tonnage and costs for punch plate	54
12.	Plant survey data summary	60
13.	Noise dosimeter tests by plant	63
14.	Plant noise levels, dBA	65
15.	Plants rank ordered by noise only	68
16.	Multiple objective ranking matrix	71
17.	Plants rank ordered by multiple objective ranking matrix	72

LIST OF TABLES (Continued)

Table		Page
18.	Plant B - jaw crusher operator sound level readings	81
19.	Plant B - noise data base	82
20.	Plant A - noise data base	84
21.	Resilient material manufacturers	86
22.	Initial cost estimate	88
23.	Control booth material and labor estimate	90
24.	Plant A - retrofit chronology	119
25.	Plant B - retrofit chronology	132
26.	Plant B - jaw crusher operator's noise control booth - sound pressure level measurements of 11 November 1980	146
27.	Noise control treatment costs	148

EXECUTIVE SUMMARY

Noise levels generated by the crushing and screening of nonmetallic minerals are regulated under 30 CFR, Part-56 "Health and Safety Standards - Sand, Gravel, and Crushed Stone Operations." Specifically Section 56.5-50 states:

> *Mandatory.* (a) No employee shall be permitted an exposure to noise in excess of that specified in the table below.
>
> PERMISSIBLE NOISE EXPOSURES

Duration per day, hours of exposure	Sound level dBA, slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

> No exposure shall exceed 115 dBA. Impact or impulsive noises shall not exceed 140 dB, peak sound pressure level.
>
> NOTE: When the daily noise exposure is composed of two or more period of noise exposure at different levels, their combined effect shall be considered rather than the individual effect of each.
>
> If the sum

$$(C_1/T_1) + (C_2/T_2) + \ldots (C_n/T_n)$$

> exceeds unity, then the mixed exposure shall be considered to exceed the permissible exposure. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level.

Interpolation between tabulated values may be determined by the following formula:

$$\text{Log } T = 6.322 - 0.0602 \text{ SL}$$

Where T is the time in hours and SL is the sound level in dBA.

(b) When employees' exposure exceeds that listed in the above table, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce exposure to within permissible levels, personal protection equipment shall be provided and used to reduce sound levels to within the levels of the table.

Enforcement of the standards has shown an acute problem in the sand and gravel and crushed stone industries.

A survey of eight selected typical plants has shown that plant operator and plant cleanup personnel exposures can be three to four times that allowed by the standard. Table ES-1 summarizes equipment and circuits at the eight visited plants. Noise level measurements (summarized in Table ES-2) identified the following noise sources as readily accessible major contributors to the overexposure problem:

a. *Screen feed chute* - Typically, the screen is fed through a steel chute from a belt conveyor. Material discharged from the conveyor impacts the walls and bottom of the steel chute. Some plant operators have installed "dead beds" in these chutes which retain a layer of material at the impact point to absorb the force of the moving material impact and to minimize wear.

b. *Screen feedbox* - Typically, the material discharging from the screen feed chute impacts a steel screen feedbox which is an integral part of the screen.

c. *Screen* - The typical screening media is either punched steel plate or woven wire cloth. Most are furnished with steel side wings. High noise levels are generated by the impact of the material on both the deck and wing liners.

TABLE ES-1. - Plant survey data summary

Plant	Production rate (tons/hr)	Equipment in use					
		Primary stage	Secondary stage	Tertiary stage	Quaternary stage	Chassis	Chutes
A	200	Stationary stage Jaw crusher - 42 × 48 in. Feeder with grizzly - 16 ft × 42 in.	Portable stage Mounted permanently to concrete pads: Cone crusher - 4-1/2 ft, rubber mounted Double deck screen - 5 × 14 ft	Portable stage Short head cone crusher - 4 ft, rubber mounted	None	Portable - OEM supplied	Manufactured on site and OEM supplied
B	200	Stationary stage Jaw crusher - 32 × 42 in. Feeder with grizzly - 16 ft × 42 in.	Portable stage Mounted permanently to concrete pads: Cone crusher - 4-1/4-ft Double deck screen - 20° incline, 5 × 14 ft	Portable stage Short head cone crusher - 4 ft, Double deck screen - 20° incline, 5 × 16 ft	None	Portable - Permanently mounted on concrete OEM supplied	Manufactured on site and OEM supplied
C All stationary	500 (est.)	Jaw crusher - 42 × 48 in. Feeder with grizzly - 60 in. × 20 ft	Cone crusher - 66 in. Triple deck screen - 6 × 16 ft crusher set very coarse	Triple deck screen - 6 × 16 ft Cone crusher - 48 in.	Cone crusher - 48 in. Triple deck screen - 6 × 16 ft	Stationary foundations	Contractor manufactured and installed
D	300	Stationary stage Jaw crusher - 44 × 48 in. Feeder with grizzly - 16 ft × 42 in.	Structural steel Mounted permanently on concrete pads: Cone crusher - 5-1/2 ft Double deck screen - 6 × 16 ft	Portable stage Mounted permanently on concrete pads: Cone crusher - 5-1/2 ft Triple deck screen - 6 × 16 ft	None	Structural steel on concrete pads	OEM supplied

TABLE ES-1. - Plant survey data summary (continued)

Plant	Production rate (tons/hr)	Equipment in use					
		Primary stage	Secondary stage	Tertiary stage	Quaternary stage	Chassis	Chutes
E All stationary	300	Jaw crusher apron feeder - 48 in. × 16 ft	Impact crusher double deck 5 × 14 ft	Short head cone crusher - 4 ft and hammermill (4033) triple deck screen - 6 × 14 ft	Final screening - double deck screen 1.95 × 4m	Concrete support	OEM supplied
F	700	Apron feeders: 2 at 48 in. × 21 ft, jaw crushers: 1 at 32 × 40, 1 at 42 × 48	Impactor-PA18-A triple deck inclined screen: 6 × 14 ft	2 Triple deck inclined screens: 6 × 16 ft, 2 triple deck inclined screens: 8 × 20 ft, 1 standard cone crusher-4-1/4 ft, 1 short head cone crusher-4 ft	Double deck inclined screen 8 × 20 ft impactor	Concrete support	Contractor supplied and installed
G All portable	125	Diesel driven jaw crusher - 30 × 42, vibrating feeder grizzly 36 in. × 12 ft	Diesel driven cone crusher - 48 in., double deck screen - 5 × 16 ft	None	None	OEM supplied	OEM supplied
H All stationary	150	Jaw crusher - 15 × 36 in. vibrating feeder grizzly - 36 in. × 12 ft.	Hydrocone crusher - 5.5 × 36 in., inclined single deck screen - 4 × 12 ft	Triple deck screen 6 × 12 ft	None	Concrete support	Field manufactured

TABLE ES-2. - Plant noise levels, dBA

Measurement location	Module operator area	Cleanup, main-tenance area	A-weighted noise levels by plant, dBA							
			A	B	C	D	E	F	G	H
Main operating booth										
Outside	x		92	94	87	-	-	-	-	-
Inside	x		73	71		-	-	-	-	-
Primary crusher										
Outside operator's booth	x		N/A	-	-	-	-	98	102[1]	-
Inside operator's booth	x		N/A	85	83	80	71	72	N/A	-
Over crusher	-	-	-	101	108	105	95	>98	>102	>100
Next to crusher discharge		x	-	-	100	-	-	-	99	-
Secondary module										
At crusher feed	-	-	>111	108	-	115	-	>104	-	110
Beside screen	-	-	112	113	106	108	113	-	109	101[2]
Base of module		x	96-98	96	-	-	99	100	103-106	92
Operator's platform	x		-	-	95[3]	-	110	94	-	93[3]
Tertiary module									N/A	
At crusher feed	-		109	108	101	103	-	>104		-
Beside screen	-	-	109	106	101	107	110	100		-
Base of module		x	95	101	102	102	91	95		-
Operator's platform	x		-	-	-	-	104	-		-

[1]No operator's booth. Reading taken at operator's stand.
[2]Operator's area above screen.
[3]Inside booth.

d. *Screen discharge* - Typically, the oversize material from the top screen deck drops to a steel plate over the crusher or directly from the screen onto a steel discharge lip.

e. *Crusher feed hopper or chute* - The feed to the crusher impacts a cylindrical/conical collection hopper that directs the feed into the crushing cavity. Often the feed to the crusher is sparse and the impacting material strikes the hopper individually. A heavily fed or choke-fed crusher has the opportunity for a bed of material to build up and therefore attenuate the noise.

f. *Crusher feed plate* - Typically, cone crushers are supplied with an abrasion-resistant metal feed plate. Material dropping into the crusher strikes the feed plate - particularly if the crusher is not choke-fed.

g. *Crusher feed cone* - Typically, the feed cone is lined with manganese steel plate for wear. The material fed to the crusher strikes the feed cone.

h. *Crusher main frame* - The shell surrounding the crushing cavity typically is impacted by discharging material from inside of the crusher. This shell acts as a noise radiator for all of the noise generated in the material reduction process from within the crusher itself.

i. *Crusher discharge* - The material discharged from the crusher is typically transferred via another steel chute to a belt conveyor which transports it to the next comminution stage or to a stockpile.

Foster-Miller Associates, Inc., under USBM Contract No. J0100038, has designed, installed, and evaluated retrofit noise control techniques in three selected crushing and screening plants.

ES.1 Plant B - Primary Jaw Crusher

The primary crushing plant at Plant B was fed run-of-mine (ROM) material from the quarry. Quarry trucks and/or front end loaders dump material into the feed hopper. The ROM material is then chute conveyed and sized by a Cedar Rapids 16 ft × 42 in. Vibrating Feeder Grizzly. The oversized material from the grizzly is fed to a Cedar Rapids* Model 3242 Jaw Crusher. The discharge from the crusher and the throughs from the feeder grizzly are conveyor-belt-transferred to a stockpile. The primary crusher is operated by one man from a stationary location. Previous attempts to reduce the operator's exposure by constructing a control booth had limited effect. The original booth had been mounted on the primary crusher frame and was not equipped with air conditioning. As a result, particularly during hot weather, the operator normally observed plant operations from the catwalk above the crusher feed.

The retrofit treatment from this plant was a new operator control booth. The booth was manufactured by Design Space International according to FMA specifications. The booth was installed on 25 November 1980 by quarry personnel (Figure ES-1). The booth was mounted on a steel support structure, erected by the quarry. The door from the booth opened onto the crusher catwalk to provide easy access for the operator. Noise levels measured after installation showed 97 dBA on the crusher catwalk and less than 80 dBA inside the booth. Adequate visibility and adequate heating and air conditioning have also been provided. A view of the booth interior showing the operator during normal plant operation is shown in Figure ES-2.

The cost of the booth was $4919 for the complete booth delivered and 40 manhours of quarry labor for installation.

ES.2 Plant B - Secondary Crushing and Screening Plant

Plant B (Figure ES-3) is an inclined screen/cone crusher, secondary portable plant. The coarse feed to the plant, -10 in., is conveyor belt fed to a steel screen feed chute and feedbox, accelerated over a 20 deg, 5 × 14 ft Nordberg inclined double-deck screen, discharged into a steel crusher feedbox, crushed in a Model 5100 Standard Symons Cone Crusher, and finally discharged

*Reference to specific equipment (Cedar Rapids Model 3242 Jaw Crusher) does not imply endorsement by the Bureau of Mines.

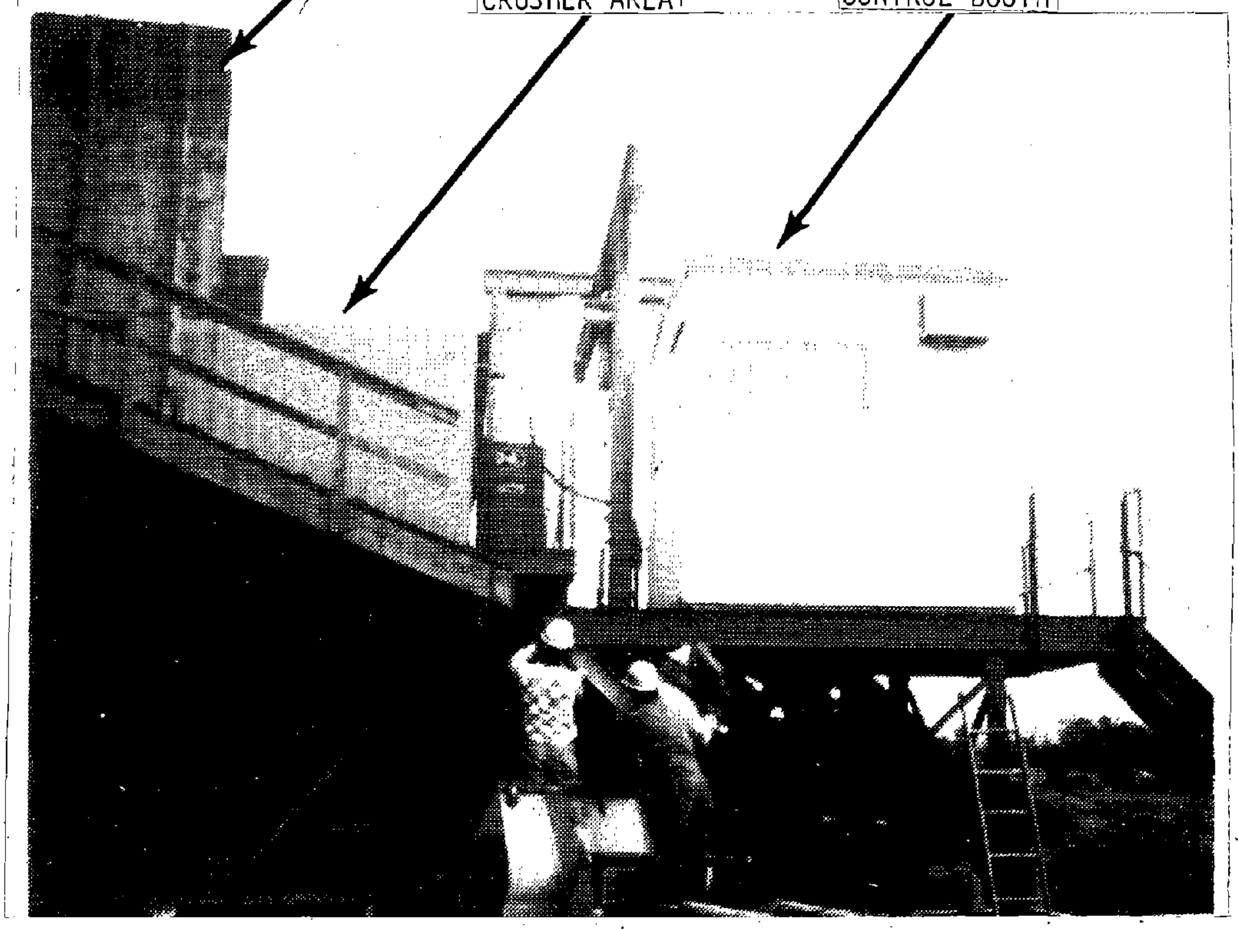


FIGURE ES-1 - New primary crusher operator control booth being installed.

FIGURE ES-2 - Inside the new primary crusher control booth during normal operation.

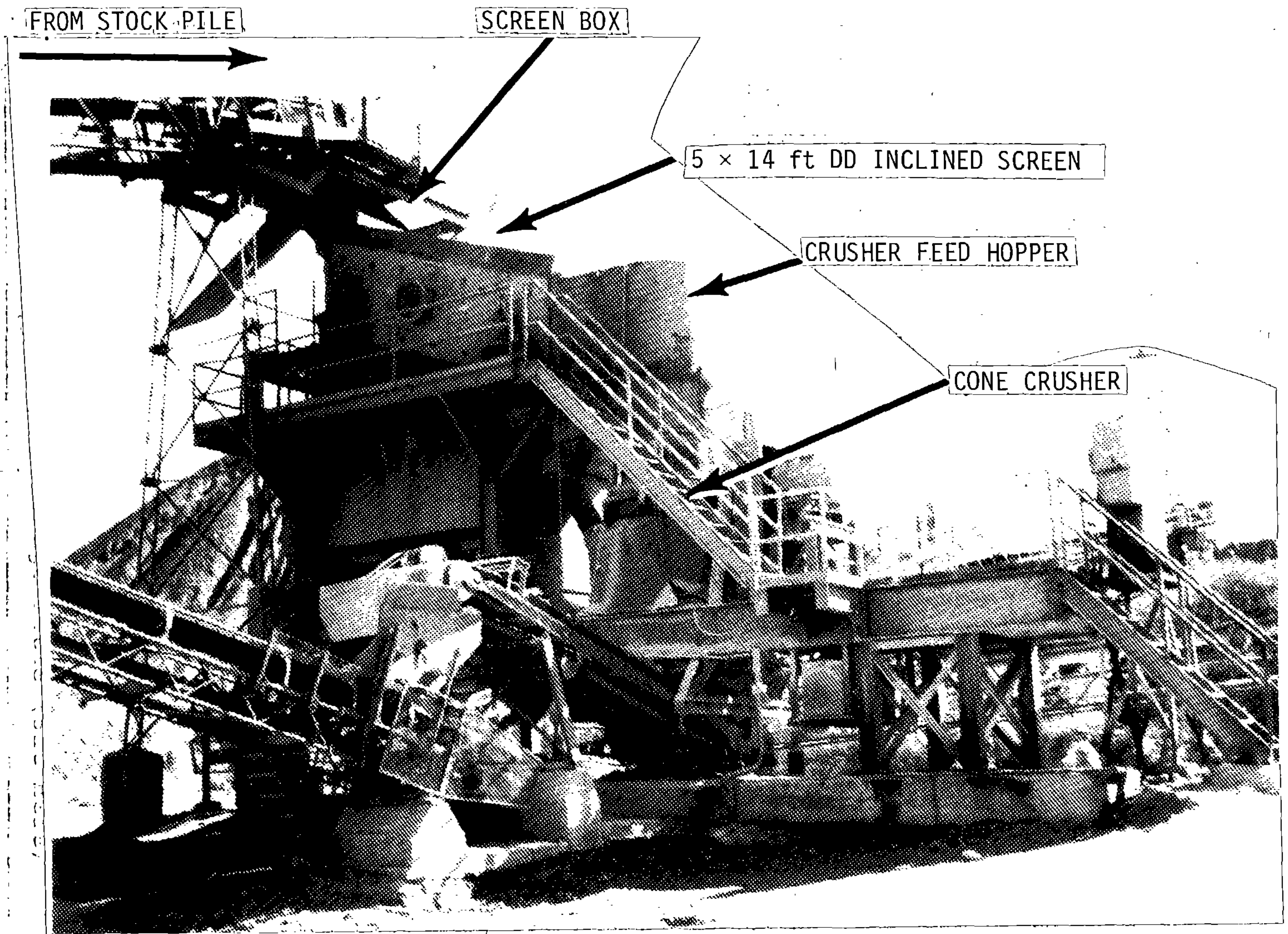


FIGURE ES-3 - Plant B - inclined screen/cone crusher secondary portable plant.

Proofer ______ Typist ______

from the plant on a transfer belt. This plant is not production-sensitive in that the screen is not overloaded and it is used primarily for separating rather than sizing. Effective screening takes place within the first one-third of the screen and both the top and bottom deck throughs are closed on the crusher feed. The crusher is not overloaded.

The following retrofit noise control treatments were installed at Plant B:

a. Resilient screen feedbox liner
b. Resilient screen top deck
c. Resilient screen wing liners
d. Resilient screen discharge lip
e. Resilient crusher feed hopper liner
f. Resilient crusher feed plate
g. Resilient crusher feed cone liners
h. Crusher noise curtain.

All installed resilient materials were steel-reinforced rubber supplied by Trelleborg Rubber Company.

All retrofit treatments, except the feed cone liners and the crusher noise curtain, were installed on 26 March 1981. Noise radiating from the crusher shell, identified after the initial retrofit treatments were installed, was reduced by the addition of the floating feed cone resilient linings and the noise curtain. Noise measurements made at plant operating positions and cleanup areas showed noise reductions of 3 to 7 dBA. These reductions, which approximately double the allowable exposure times in these areas, should reduce cleanup and maintenance personnel exposure levels to within those specified by the standard.

The performance of the installed materials was monitored from 26 March to 21 October 1981. During this period, Plant B had processed approximately 198,000 tons. The observed wear of the materials during this period has been minimal. Through 21 October 1981, the screen feedbox liners and discharge lip are showing some dishing at the primary material path (Figure ES-4). The screen cloth (Figure ES-5) has rounded at the edges of the material sizing holes.

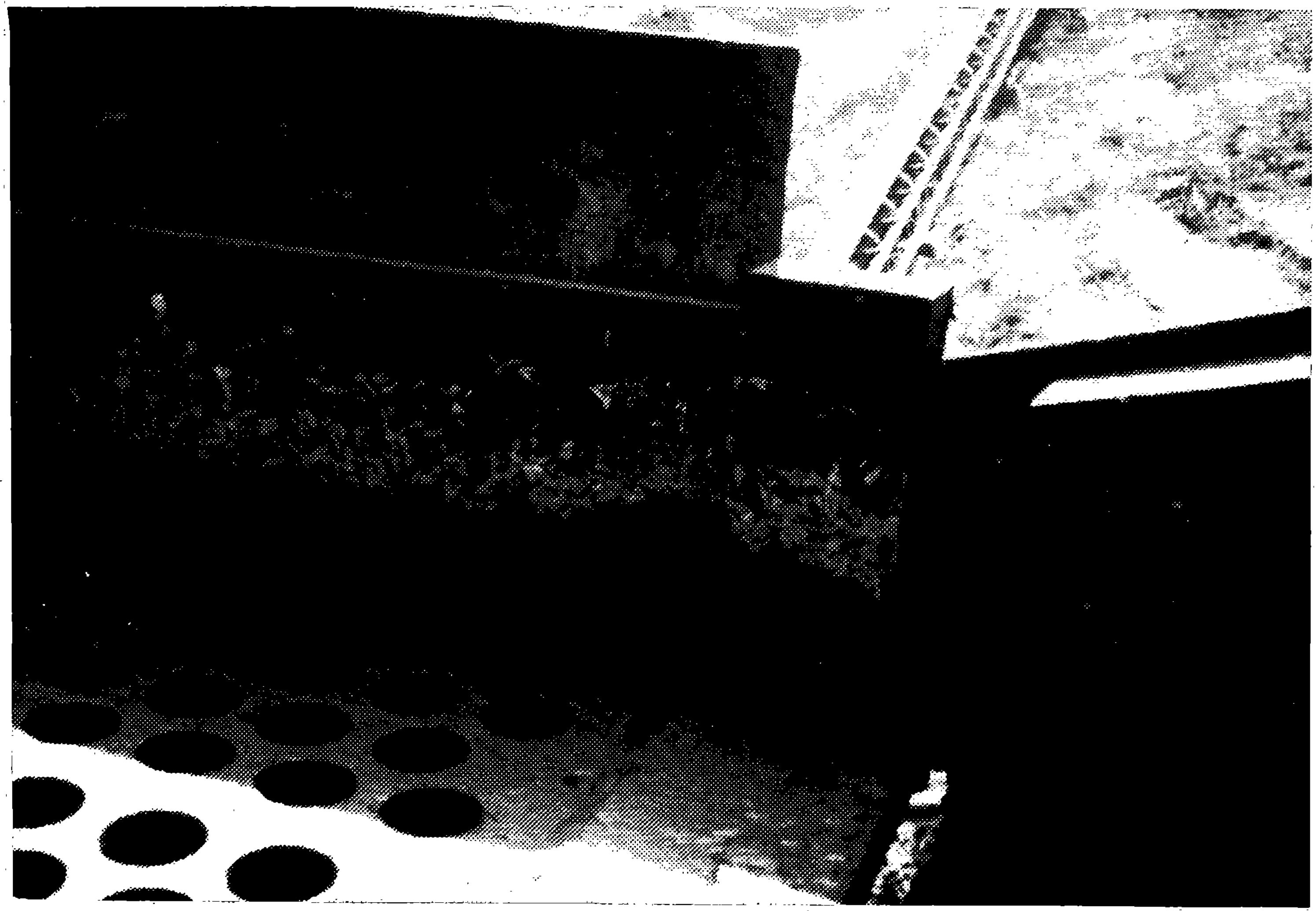


FIGURE ES-4. - Plant B - resilient screen discharge lip after processing 198,000 tons.

FIGURE ES-5. - Plant B - resilient screen deck after processing 198,000 tons.

The crusher feed hopper liner and screen wing liners have shown virtually no wear (Figure ES-6). The resilient crusher feed plate (Figure ES-7) did wear prematurely due to its being manufactured undersized. It was later replaced with a new resilient feed plate (Figure ES-8).

Part of the crusher feed cone liner also failed prematurely. Two of the seven installed lining segments came loose and passed through the crusher. Noise produced from the crusher shell was reduced after the lining failure by installing a sound barrier curtain around the exterior of the crusher shell (Figure ES-9).

The total costs of the installed materials at Plant B were $14,003. Installation required 66 hr of quarry labor.

ES.3 Plant A — Secondary Crushing and Screening Plant

Plant A (Figure ES-10) is a horizontal screen/cone crusher secondary portable plant. The coarse feed to the plant, -10 in., is conveyor belt fed to a steel screen feed chute and feedbox. The feed to this plant contains more coarse feed than Plant B and the material is not accelerated over the screen as much as at Plant B. The screen is a 5 × 14 ft Cedar Rapids horizontal double-deck screen. In the original plant, the oversized material from the top deck discharged into a 4-1/4 ft Standard Symons Cone Crusher. During the program, the plant operator changed over to a Model 1500S Telsmith cone crusher. The plant was also modified to feed the oversized material from both the top and bottom screen decks to the crusher. These modifications were made between the design and installation phases of the program, which resulted in extensive field modifications and remanufacturing of the noise control retrofit treatments.

The following retrofit noise control treatments were installed at Plant A:

a. Resilient impact pads on the wall and bottom of the screen feed chute

b. Resilient screen feedbox liner

c. Resilient screen top and bottom decks

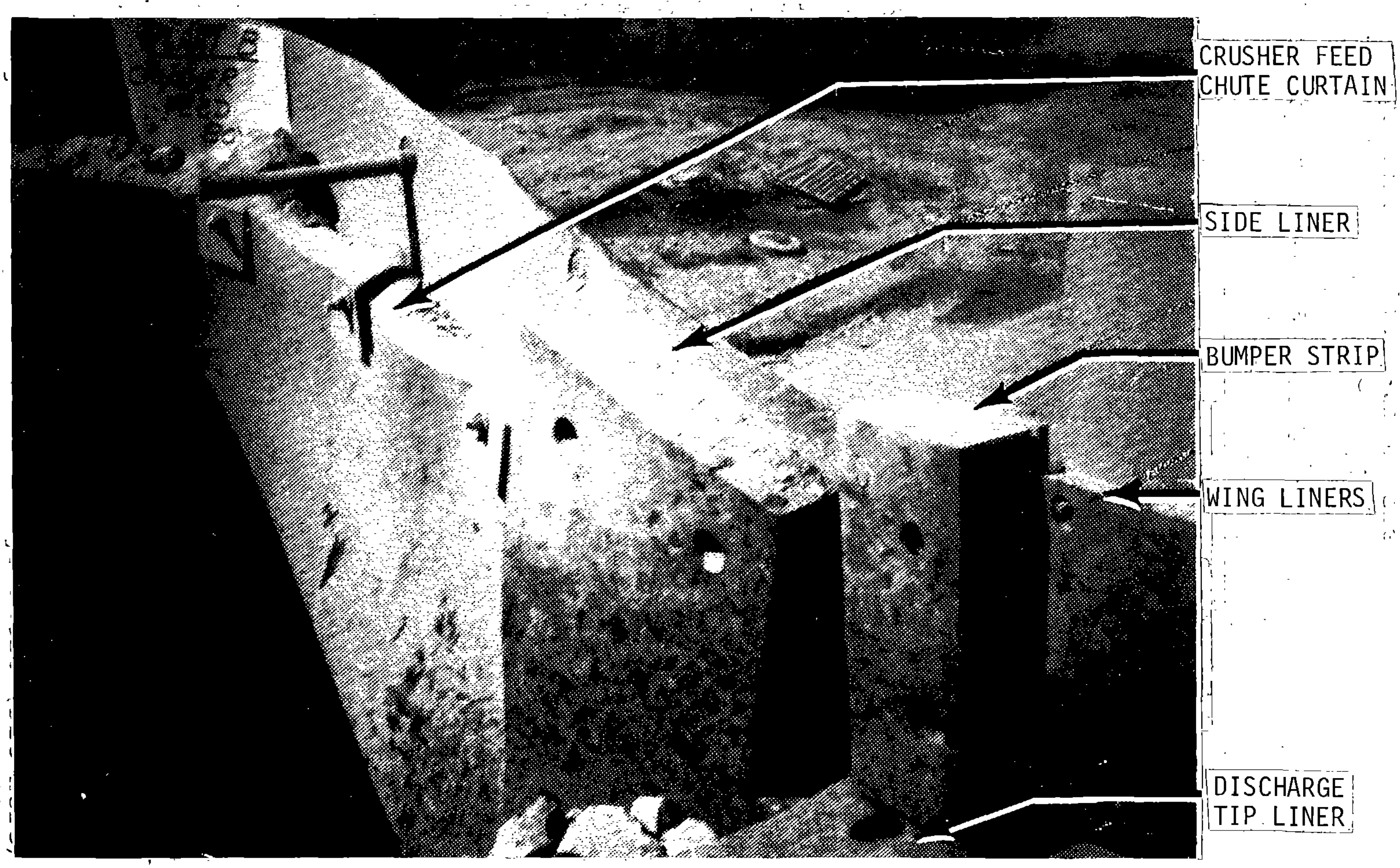


FIGURE ES-6. - Plant B - crusher feed hopper liner after processing 198,000 tons.

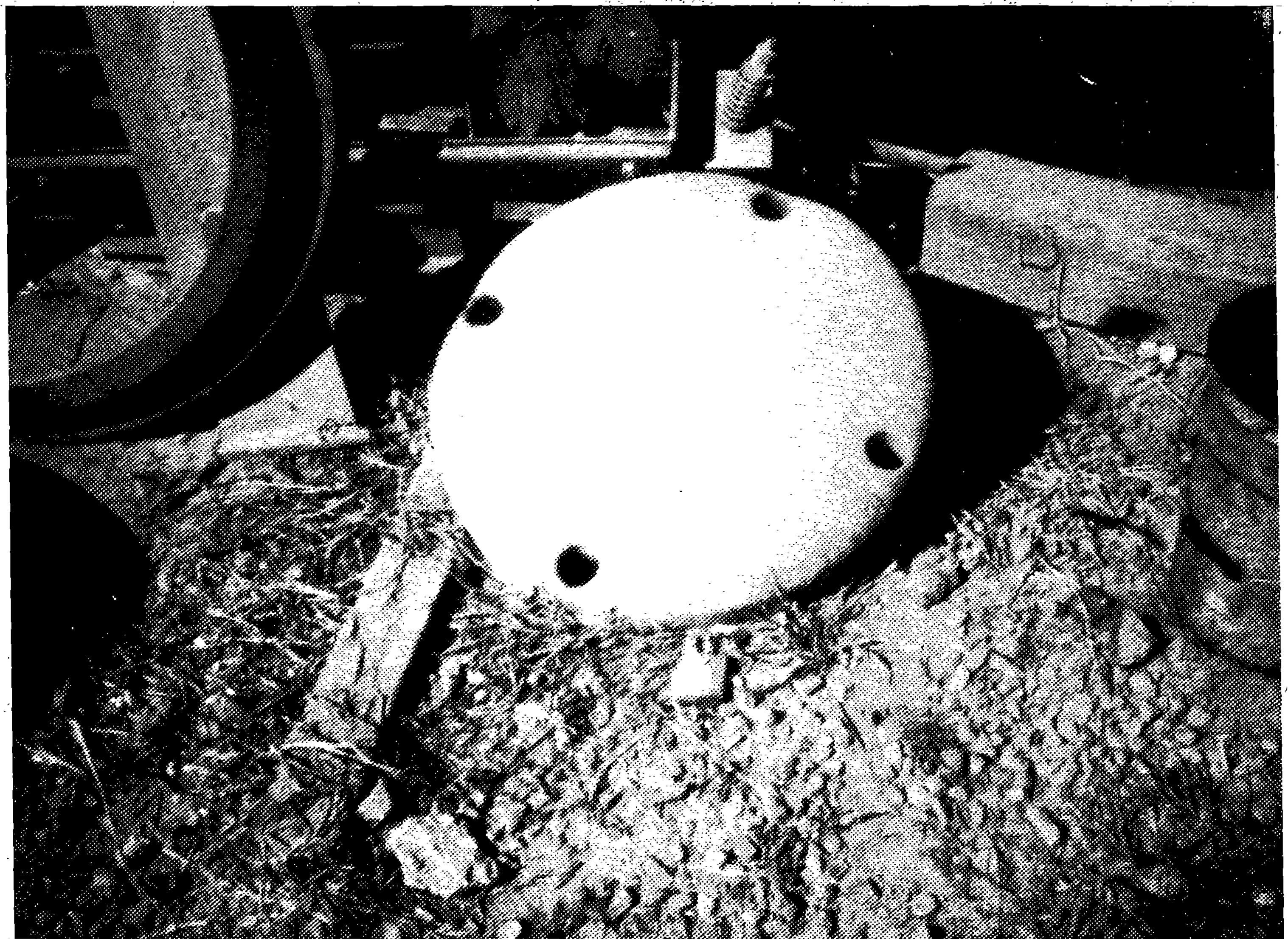


FIGURE ES-7. - Plant B - original resilient crusher feed plate showing premature wear around the mounting bolts.

FIGURE ES-8. - Plant B - new resilient crusher feed plate being installed.

Figure 1-1. Vertical Full Page Title (Sit Here)

Proofer ______________ Typist ______________

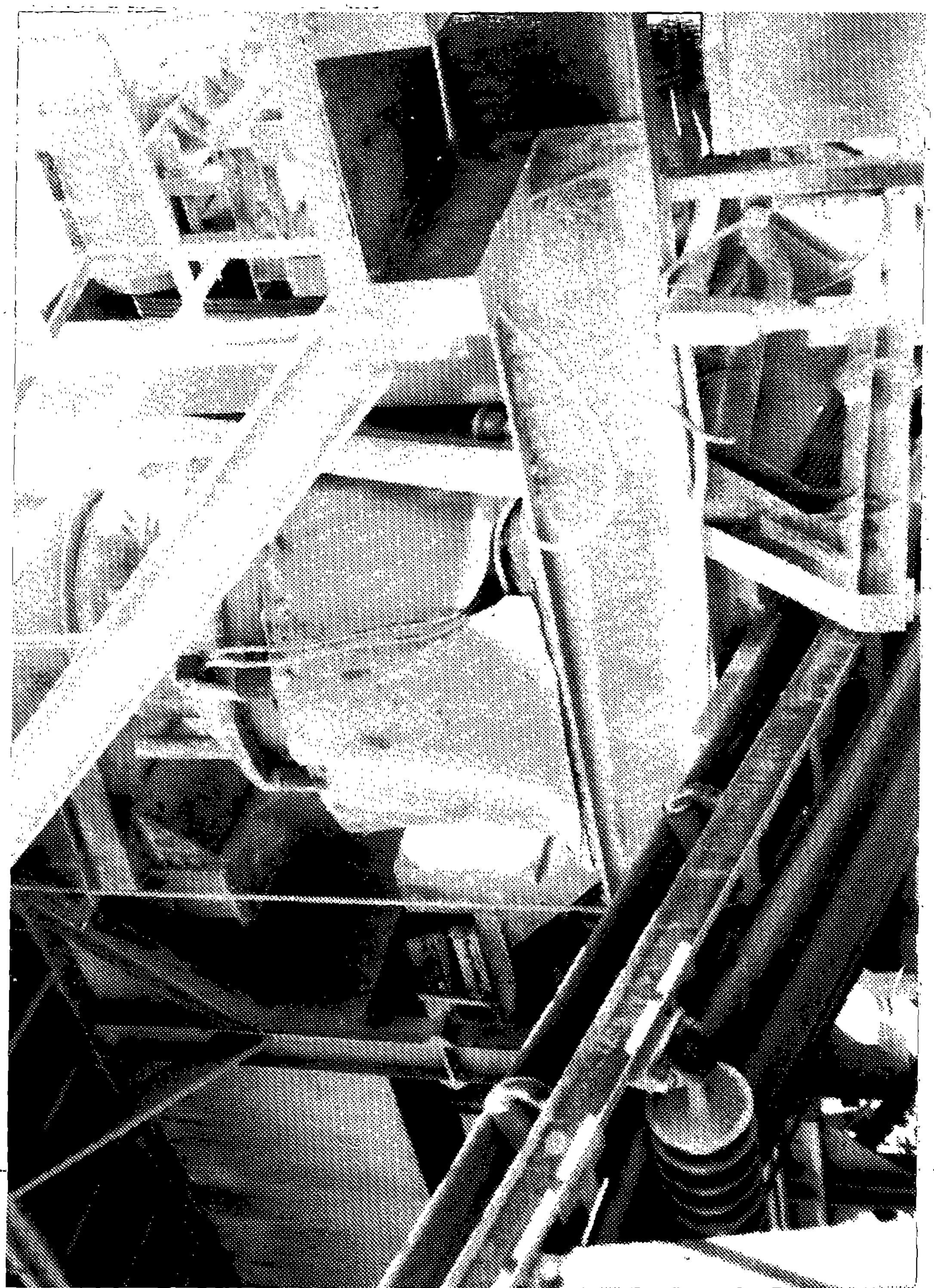


FIGURE ES-9 - Plant B - noise control curtain installed around the crusher mainframe.

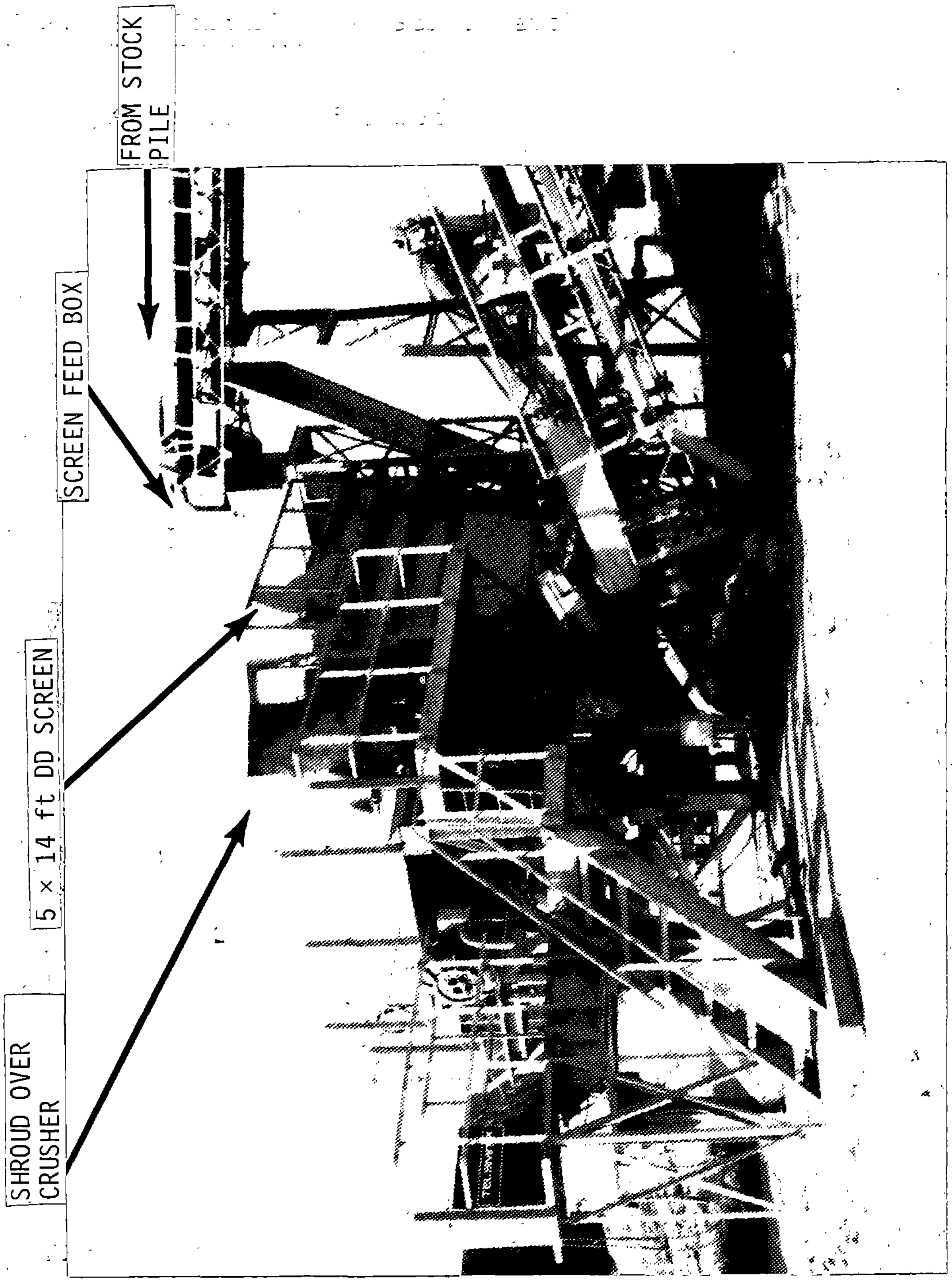


FIGURE ES-10. - Plant A - horizontal screen/cone crusher secondary portable plant.

Figure 1-1. Vertical Full Page Title (Sit Here)

Proofer ______________ Typist ______________

-2 6/80

d. Resilient screen wing liners

e. Resilient screen discharge lip

f. Resilient crusher feed hopper liner.

All installed materials were steel-wire-reinforced urethane supplied by Durex Products, Inc.

The screen feed chute impact pads, crusher feed hopper liner, and top screen deck were installed on 30 April 1981. The screen discharge lip (which required remanufacturing because of plant modifications) the screen side wing liners and screen feed chute bottom liners were installed on 9 June 1981. Noise measurements made after this installation showed that replacing the bottom deck with resilient media was also required. This modification was performed on 23 June 1981.

The installed treatments at Plant A showed significant noise reductions near the primary sources. Significant reductions at ground level cleanup and operation locations, however, were never achieved. Premature wear of installed components coupled with the need for remanufacturing mis-sized components (due to plant modifications) prevented a successful progressive retrofit program at this plant. For example, the impact pad installed on the wall of the screen feedbox had failed prior to the installation of the screen discharge lip. The screen top deck had failed prematurely and was being replaced by the quarry operator before the bottom deck could be delivered and installed. Figure ES-11 shows the wornout top deck after processing only 191,000 tons.

By the end of the monitoring program in October 1981, all resilient materials except the bottom screen deck and crusher feed hopper liner had been replaced. The crusher feed hopper had worn to the reinforcing wire as shown in Figure ES-12. The screen bottom (Figure ES-13) deck was also nearing the point of replacement after processing 212,000 tons.

The material costs at Plant A totaled $17,085. Installation required 69 hr of quarry labor.

FIGURE ES-11 - Plant A - resilient top screen deck after processing 191,000 tons.

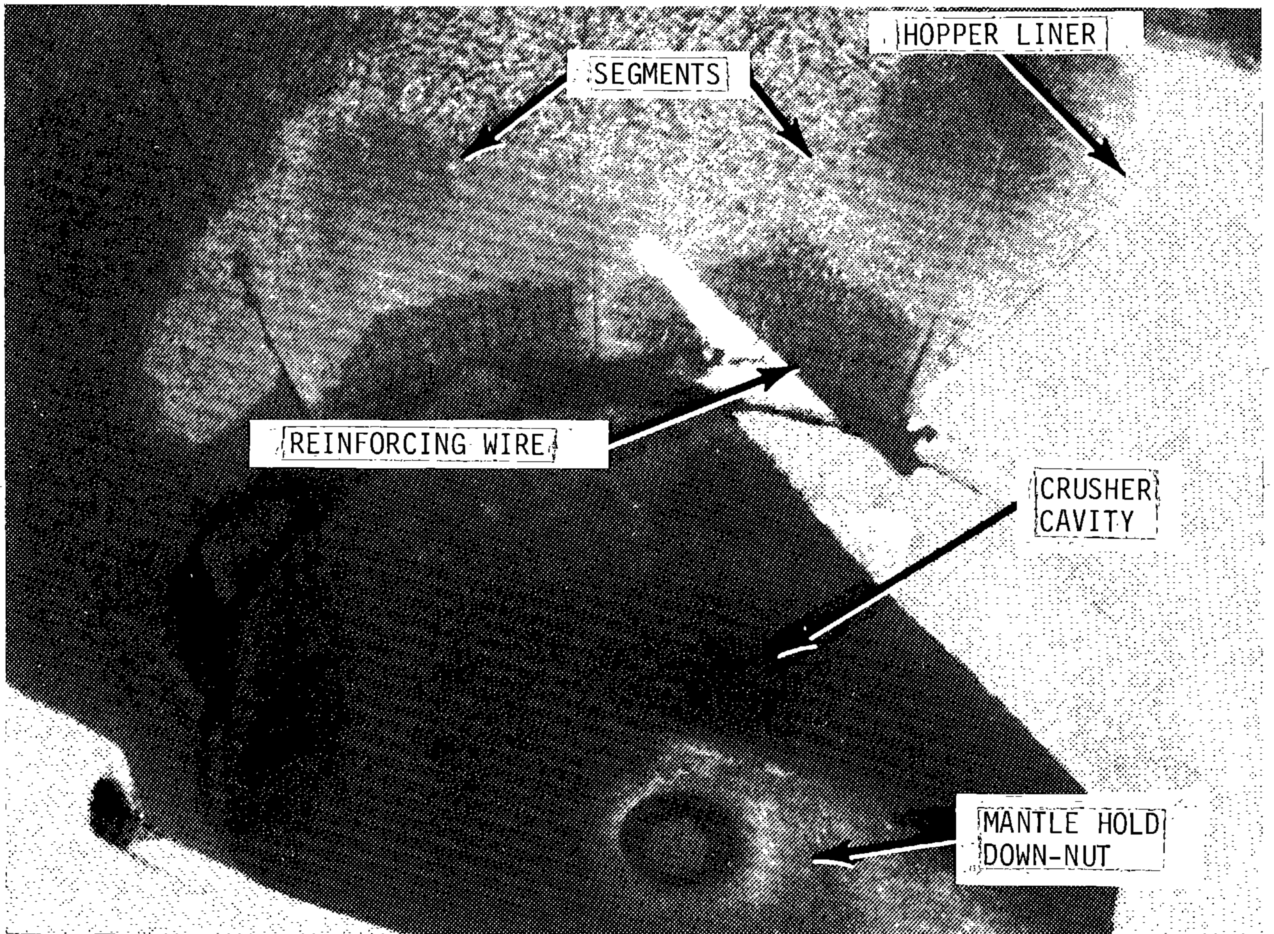


FIGURE ES-12. - Plant A - resilient crusher feed hopper liner after processing 480,000 tons.

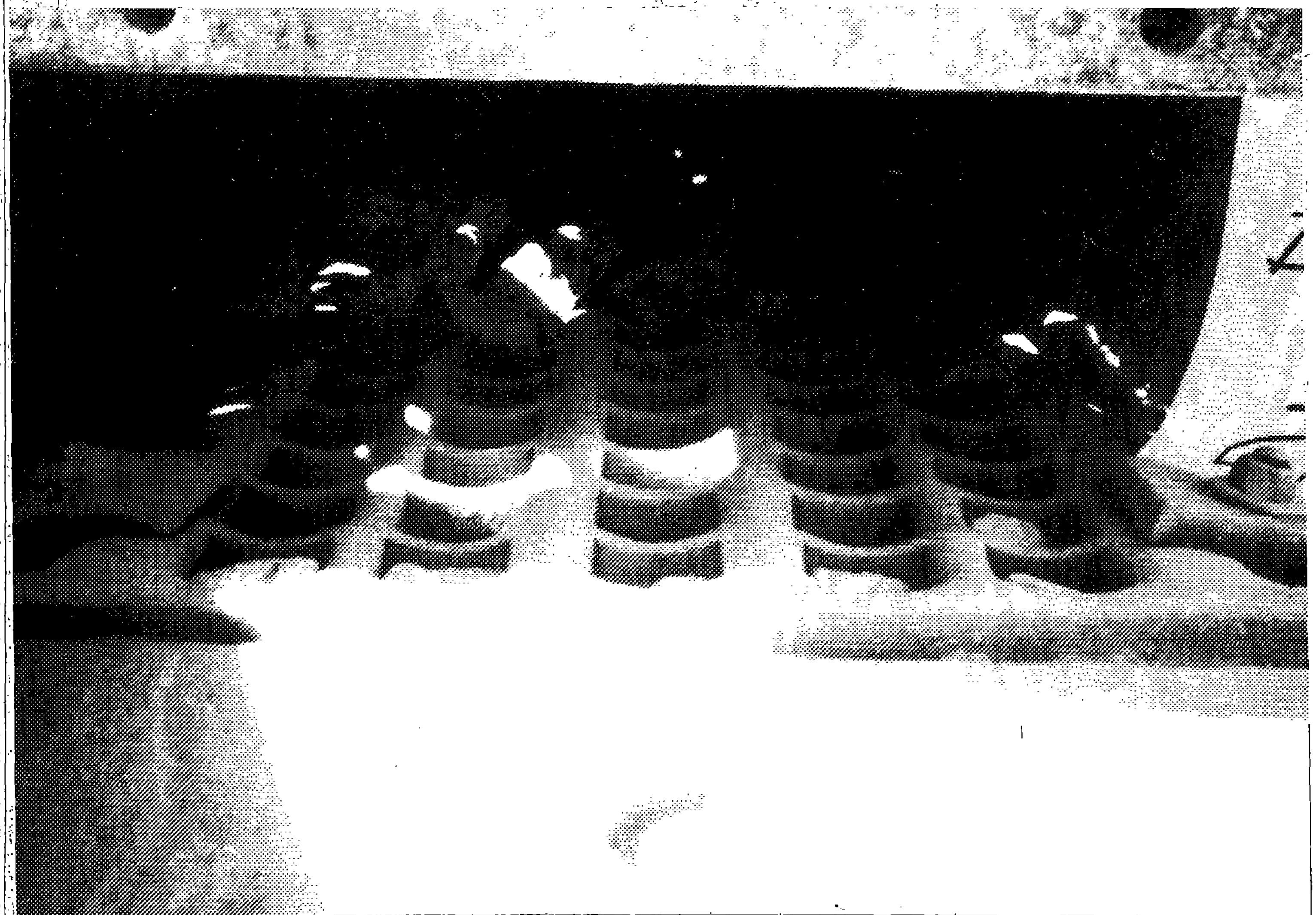


FIGURE ES-13 - Plant A - resilient bottom screen deck after processing 212,000 tons.

ES.4 Conclusions

Treatment techniques employed the use of advertised commercially available resilient wear materials that could be practically applied by the smallest and largest operators. Treatment costs for the portable plants were kept to about 5 to 7 percent of the purchase price of a new 200 to 300 tons/hr plant. Reasonably maintained plants invest this amount annually to repair material handling equipment or transfer points. Care was taken not to adversely affect the performance of the comminution circuit or the equipment utilized in the circuit. The wear performance and noise reduction versus cost of the rubber products utilized during this program have led FMA to conclude that retrofit noise treatment can be economically applied to portable plants.

It is also reasonable to assume that new portable plants can incorporate this technology into their manufacturing process and address additional sources. A retrofit program only addresses field-accessible areas; but, new plants can be designed and fabricated to incorporate resilient materials for improved wear and noise control. Cost tradeoffs for new plants are possible when wear-resistant resilient materials are substituted for abrasion resistant (AR) metals. The justification for incorporating cost-effective noise treatments in portable plants, without substantially affecting productivity in the secondary circuit, has been established with this program.

1. INTRODUCTION

This document is the Final Technical Report for USBM Contract No. J0100038, "Demonstration of Noise Control Techniques for the Crushing and Screening of Nonmetallic Minerals." The report presents the details of a survey of the nonmetallic mining industry, the design and installation of retrofit noise control treatments for three crushing and screening plants, and the field evaluation of those controls under actual operating conditions.

1.1 Background

The permissible noise exposures of workers in the crushing and screening of nonmetallic minerals is regulated under 30 CFR 56.5-50. Under this regulation, 90 dBA is the maximum sound level to which an employee can be exposed for 8 hr on a given working day; for every 5 dBA increase in sound level above 90 dBA, the permissible exposure period is halved. Under current regulations, exposure to levels below 90 dBA does not contribute to the worker's daily noise dose. Under an anticipated regulation, the noise-level-versus-permissible-daily-exposure curve shown in Figure 1 is extended (indicated in the figure by the dotted portion of the curve) to include a 16-hr exposure at 85 dBA. Thus, under the anticipated regulation, exposure to noise levels less than 90 dBA would contribute to a worker's daily noise exposure.

Many of the workers in nonmetallic crushing and screening plants are exposed to levels that exceed those allowed by the regulation. For instance, typical noise levels for screens and crushers range from 95 to 115 dBA, with average operator exposure times as high as 6 to 8 hr. Portable plants, it was felt, create an especially acute exposure problem. Because of the approximately 12,000 portable and stationary nonmetallic processing plants currently in operation, the impact of crushing and screening noise on the health of employees in this industry is severe.

To control noise in the crushing and screening of nonmetallic minerals, three problems must be solved:

a. The prevalent sources of crushing and screening noise in both portable and stationary plants must be identified.

b. Appropriate retrofit noise control treatments for these sources must be designed.

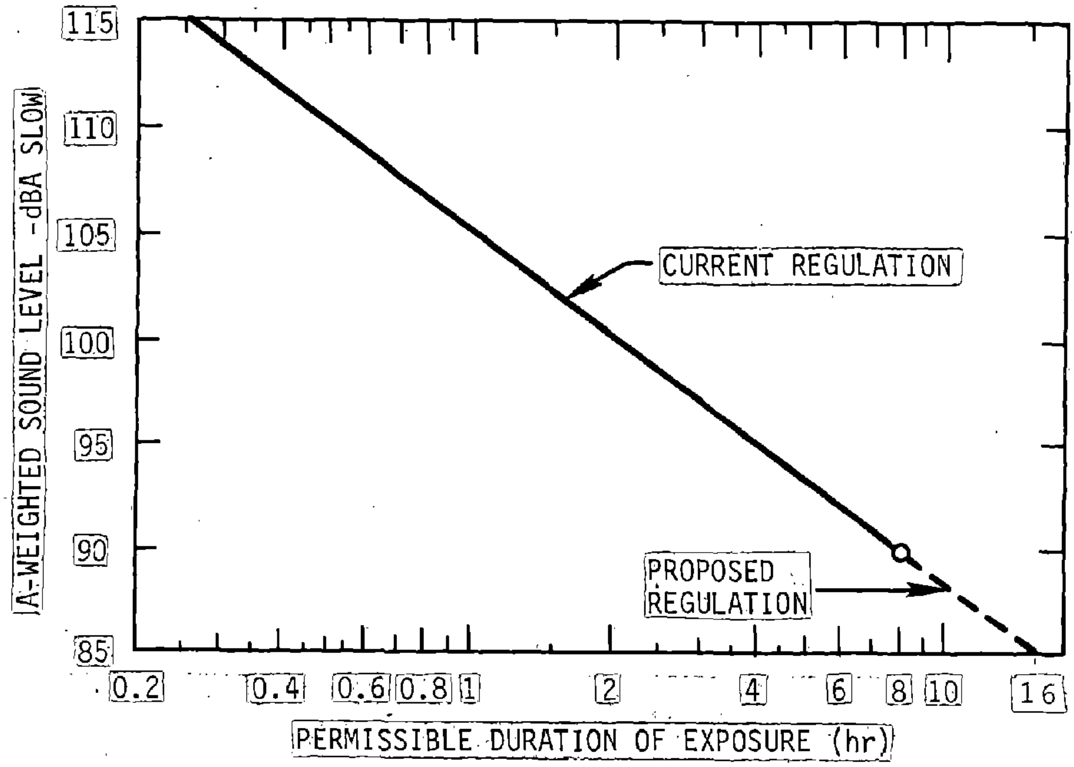


FIGURE 1. - Noise level versus permissible daily exposure.

c. The noise control treatments must be field tested under actual operating conditions to demonstrate both their noise control effectiveness and their durability.

1.2 Objectives

The broad objective of this program was to develop and demonstrate retrofit noise control techniques for the crushing and screening of nonmetallic minerals in portable processing plants.

Specific contractual objectives of the program included the following:

a. Identify the prevalent sources of crushing and screening noise in both portable and stationary plants.

b. Design appropriate retrofit noise control treatments for those sources.

c. Field test noise control treatments under actual operating conditions.

1.3 Scope of Effort

The program was to be completed in three phases:

1. Phase I - Noise Survey
2. Phase II - Retrofit Treatment Design
3. Phase III - Field Demonstration.

Phase I effort included performing a census of the nonmetallic mining industry to determine the number and types of equipment used in the crushing and screening of nonmetallic minerals, and then conducting visits to eight plants to make noise surveys. The purposes of the visits were to:

a. Identify the operational and mechanical constraints that must be considered in designing and implementing retrofit controls

b. Assess the nature of the noise sources so that appropriate control technology could be selected

c. Determine worker noise exposures that are representative of crushing and screening operations.

Phase II effort included the following:

a. Final site selections and cooperative agreements
b. Preliminary design of retrofit noise controls
c. Follow-up plant visits
d. Final design.

The final design consisted of engineering drawings, material specifications and material and installation cost estimates for retrofitting three selected plants.

Phase III was a field demonstration which included:

a. Purchasing, fabricating, and installing noise control treatments

b. Field testing the installed treatments to determine:

1. The effectiveness of treatments for reducing noise levels and thereby reduce worker exposure.

2. The wear properties of the retrofit materials, including any changes in the initial noise reductions.

2. INDUSTRY SURVEY

A census of the nonmetallic mining industry was performed to determine the number and types of equipment used in the crushing and screening of nonmetallic minerals, and to select eight plants for on-site visits. The purposes of the on-site visits were to:

a. Identify the operational and mechanical constraints that must be considered in designing and implementing retrofit controls

b. Assess the nature of the noise sources so that appropriate control technology can be selected

c. Determine worker noise exposures that are representative of crushing and screening operations.

This section summarizes the results of the census and on-site visits.

2.1 Census of Nonmetallic Mining Industry

Extensive surveys of the sand and gravel and crushed stone industries were performed in 1974 and partially updated in 1979 by the staff of the trade magazine *Pit and Quarry*. The 1974 *Pit and Quarry* survey included mailed questionnaires to 3000 plant managers from a total United States population of approximately 12,000 sand and gravel and crushed stone operations. A total of 562 useable questionnaires were returned. Of these:

a. 362 (64.4 percent) were from sand and gravel operations

b. 200 (35.6 percent) were from stone quarry operations.

Reported annual production was:

a. 283 plants (50.3 percent) < 200,000 tons

b. 152 plants (27 percent) - 200,000 to 500,000 tons

c. 74 plants (13.1 percent) - 500,000 to 1,000,000 tons

d. 53 plants (9.4 percent) > 1,000,000 tons.

The results of the surveys were made available to FMA for this program. FMA confirmed the data through:

a. Discussions with equipment manufacturers and users at an international equipment exposition

b. Telephone interviews with the plant managers for large quarry equipment users, and a number of randomly-selected small operations

c. Telephone interviews with equipment manufacturers including:

1. Allis-Chalmers
2. Hewitt-Robins, Division of Litton Industries
3. Iowa Manufacturing Co.
4. Nordberg, Division of Rexnord Incorporated
5. Telsmith, Division of Barber-Greene.

Survey results are summarized in the following subsections.

2.1.1 Crusher Statistics

Table 1 presents *Pit and Quarry's* tabulation of crushing units by stages from their 1974 survey. The table illustrates that *a jaw crusher is the most popular for first stage* crushing and *the cone crusher is the most popular for secondary, tertiary, and quarternary stages*. Table 2 lists the crushers by type and manufacturer's market share. Table 3 lists the crushers by type and size distribution. In Table 3, jaw crusher size is listed by the mouth opening in inches and by the mouth width. The gyratory is listed by the largest diameter rock in inches that can enter the crushing cavity. The impactor size is determined by the rotor diameter and by the rotor width, which is the same as the maximum width of a rock in inches that can enter the machine.

The jaw, gyratory, and impact crusher sizes are designated in a manner that allows the user to estimate the maximum dimensions of the run-of-mine (ROM) material that he must quarry or liberate from its parent strata. A crusher accepting a maximum size rock of 30 × 42 in. is typical for a portable plant using truck haulage or front end loader haulage from the quarry to the plant.

TABLE 1. - Crusher population by crushing stages (1)

Crusher	Total population	Crushing Stages			
		First	Second	Third	Fourth
Jaw	9,758	8,499	1,103	156	-
Hammermill	2,586	401	1,337	670	178
Impactor	2,069	1,289	546	195	39
Gyratory	3,985	1,359	1,765	821	40
Cone	8,570	746	4,833	2,374	617
Roll-Single	489	75	225	189	-
Roll-Double	3,984	434	1,689	1,343	518
Roll-Triple	419	-	251	126	42
Roll-Quad	140	-	35	105	-
Cage Mill-Single	252	72	180	-	-
Cage Mill-Multi	140	-	-	93	47

The cone crusher size is a designation of the diameter of the gyrating head. Its utility is best served in the secondary and tertiary crushing stages. The material that a cone crusher sees has already been through a reduction stage and the head size designation is more indicative of a feed by volume rather than size.

Based on *Pit and Quarry's* survey, 71 percent of the current crushers are mounted on stationary supports and 29 percent are portable. These numbers, however, may be misleading. Respondents to the survey may have been confused by portable plant and stationary plant classification questions. For example, it is not unusual for an operator to buy a crusher on a portable chassis and then to permanently mount the chassis on concrete footings. The unit can then be considered stationary. However, the plant still has the flexibility and characteristics of a portable plant in that it can be moved readily to a new location intact and can be set up very quickly and with a minimum cost.

TABLE 2. - Crushers by type and manufacturer's market share (1)

Manufacturer	Percent market share by type			
	Jaw	Gyratory	Cone	Hammermill
Acme	0.4			
Allis-Chalmers	2.2	34.5	8.7	
American				4.0
Austin Western	5.1			
Badger	0.7			
Birdsboro	0.4			
Bulldog				2.7
Diamond	4.0			
Eagle Crushers	0.7			5.4
El Jay	0.4	0.9	5.4	
Farrell-Bacon	1.8			
Gilson				2.7
Good Roads	0.7			
Gruendler	0.4			6.8
Hewitt-Robins	2.2			2.7
Iowa Manufacturing Co.	24.0			33.8
Kennedy-Van-Saun	1.1	8.0	1.7	
Kue Ken	2.2	2.7	0.8	
Lima-Baldwin-Hamilton	0.4			
Lippmann	4.7			2.7
McCulley		1.8		
Micro Pulverizer				4.0
Missouri Rogers	4.7			1.4
New England	0.7	0.9		
Nordberg		15.0	56.2	
Pennsylvania				5.4
Pettibone				1.4
Pioneer Division, Portec Inc.	12.7			
Reliance	0.4			
Stoll				1.4
Telsmith	7.3	11.5	13.2	
Traylor	3.3	15.0	0.8	
Universal Engineering	10.5			9.4
Webb	0.3			
Williams				5.4
No Name	8.7	9.7	13.2	9.4
	100.0	100.0	100.0	98.6

TABLE 3. - Crushers by type and size distribution (1)

Size (in.)	Percent	Size (in.)	Percent
Jaw		Impactor	
8 by 24	0.4	10 by 20	2.8
9 by 16 to 36	1.8	22 by 22	2.9
10 by 16 to 40	33.2	20 by 20 to 42	22.8
11 by 20	0.4	32 by 20 to 35	5.7
12 by 20 to 48	6.6	33 by 42	2.9
13 by 36	0.9	36 by 42 to 55	25.7
14 by 24 to 28	3.1	37 by 55	2.9
15 by 24 to 38	6.6	38 by 50	2.9
18 by 24 to 38	7.4	43 by 36 to 40	25.7
20 by 30 to 36	5.2	44 by 42	2.9
21 by 36	0.9	46 by 54	5.7
22 by 30 to 48	3.9	53 by 48 to 60	8.6
24 by 36 to 48	3.5	55 by 53	5.7
25 by 40	2.6	56 by 60	2.8
28 by 36	0.4		[illegible]
30 by 36 to 48	10.9		
32 by 40 to 42	2.6	Cone	
36 by 42 to 48	2.2		
40 by 48	0.4	24	3.2
42 by 30 to 60	4.4	28	1.3
48 by 60	2.2	36	25.5
60 by 84	0.4	37-1/2	1.3
	100.0	38	0.6
		45	1.3
Gyratory		48	32.5
		51	14.0
10	1.6	54	5.1
12	3.1	57	1.3
18	3.1	60	0.6
19-1/2	1.6	66	10.2
20	1.6	72	0.6
24	4.7	84	2.5
25-1/2	1.6		100.0
28	3.1		
30	7.8	Hammermill	
36	14.0		
37-1/2	3.1	12 by 24	2.9
42	17.2	20 by 33	2.9
45	1.6	24 by 32 to 36	11.8
48	12.5	30 by 30 to 40	32.4
51	4.7	36 by 38 to 40	5.9
60	14.0	40 by 30 to 36	38.3
66	3.1	41 by 36	2.9
72	1.6	42 by 24	2.9
	100.0		100.0

Proofer ____________ Typist ____________

2.1.2 Screen Statistics

Table 4 summarizes the *Pit and Quarry* survey data for screen installations. Inclined screens are installed as stationary screens 83 percent of the time and only 17 percent are installed as portables. Horizontal screens have their greatest utility in portable plants. Overall, inclined screens are the most popular and outsell horizontal screens by about 3 to 1.

Inclined screens are normally installed at an inclination of 15 to 20 deg. Gravity and machine-induced material inertia accelerate the product bed. Most inclined screens are a constant circular throw of about 1/2 in. The motion is controlled by an eccentric driven by a "V" belt drive. The motion can be with-the-material flow for large material (2 to 6 in.) or counterflow for smaller material or for longer retention of the material on the screen deck. The smaller the material being screened, the smaller the throw. The throw is adjusted by changing the counterweights on the cross-frame drive shaft.

Low headroom requirements, common in portable plants, require horizontal screens. Horizontal screens, however, do not have the capacity of inclined screens because gravity is not used to promote material flow. Motion is imparted to the screen decks in the same manner as the inclined screen. The motion can be circular, elliptical, straight line, with-flow or counterflow.

Table 5 tabulates the relative popularity of screens by manufacturers. No data were available breaking down this tabulation into inclined and horizontal screen fractions. Most screen manufacturers produce both types. Table 6 tabulates the screen population by size. Again, no distinction is made between inclined and horizontal screens.

2.1.3 Screening Media

Pit and Quarry's survey was further confirmed by an in-depth study by Twin City Wire Cloth Division of Minnesota Fence and Iron Works in September of 1979. Their survey was made of the original screen equipment manufacturers and the producer members of the National Limestone Institute. The study sought answers to the following questions:

a. What are the advantages and disadvantages of the most popular screening media?

TABLE 4. - Screen statistics (1)

Description	Type of screens: Inclined screens	Horizontal screens	Rotary screens	Totals
Number in use per plant	2.71	0.93	0.10	
Number in use in industry	37,886	11,243	1,398	50,527
Estimated annual purchase	5,781	1,988	216	7,985
Physical characteristics				
Vibrating, %	96.6	95.1	-	
Non-vibrating, %	3.4	4.9	-	
Stationary, %	83.2	59.9	-	
Portable, %	16.8	40.1	-	
2-Bearing, %	69.5	19.4	-	
4-Bearing, %	30.5	80.6	-	

NOTES:

1. At the present time, 15.3 percent of all screens are enclosed

2. Percent of plants that have installed screens in the past 3 years = 26.5

3. Percent of plants planning to buy screens in the next 12 months = 24.0 yes
   0.9 maybe
   75.1 no

TABLE 5. - Relative popularity of screens by manufacturer (1)

Percent	Manufacturer	Percent	Manufacturer
0.7	Aggregates Equipment, Inc.	0.6	Kennedy-Van-Saun
10.0	Allis-Chalmers	2.9	Link Belt
0.3	Barber-Greene	0.6	Lippmann
0.3	Bonded Scale	0.3	Niagara
0.1	Bodinson Manufacturing Co.	2.6	Nordberg
0.1	Carrier	0.5	Overstrom
0.1	Century	0.1	Orville-Simpson
0.1	Clark	0.3	Peerless
0.4	Diamond	5.6	Pioneer Division, Portec Inc.
4.5	Deister	0.1	Rogers
0.1	Derrick	0.1	Rotex
0.1	Eagle Crushers	6.7	Screen Equipment Co.
2.4	El Jay	10.8	Simplicity Engrg.
11.9	Hewitt-Robins	0.1	Stephens-Adamson
0.1	Huron	0.7	Syntron
11.6	Iowa Manufacturing Co.	3.6	Telsmith
0.4	Jeffrey	15.6	W.S. Tyler Company
0.9	Kolberg	1.6	Universal Engrg.
1.8	Kolman	1.3	Shop made
		100.0	

TABLE 6. - Percent of screen population by sizes (1)

Length (ft)	Width (ft) 2	2-1/2	3	3-1/2	4	5	6	7	8	10	14	20
3			0.1									
4	0.2	0.3	0.2					0.1			0.1	
5			0.4	0.1	0.9		0.1					
6	0.2		3.2		2.0	0.2						
7				0.2						0.2		
8	0.2		4.3	0.1	5.5	0.2			0.1			
9			0.1		0.2							
10			1.9	1.3	11.0	3.1	0.3					
11					0.1							
12			0.7	0.1	14.2	10.7	0.9		0.6			
13												
14		0.1		0.1	3.1	10.9	1.5	0.2	0.1	0.1		
15			0.2		0.2	0.1	0.1					
16			0.1		0.8	5.5	8.9	0.4	0.3			
17												
18						0.2			0.1			
19												
20					0.3	0.2	0.1	0.5	1.6			
21												
22												
23												
24				0.1								0.1
TOTALS	0.6	0.4	11.2	2.0	38.3	31.1	11.9	1.2	2.8	0.3	0.1	0.1

b. What are the most important factors in selecting a screening media?

c. What is the cost of a particular media per ton of throughput?

Twin Cities ran a second survey for the purpose of determining the relative importance of buying motives. Producers in the National Limestone Institute were asked to rank in order the following factors:

a. Sizing accuracy

b. Screen media life

c. Throughput

d. Price

e. Availability.

The results of these two surveys are shown in Table 7. The results show that sizing accuracy and throughput are the most important. If the first and second most important concerns are combined, sizing accuracy and throughput carry the same amount of importance as buying motives.

TABLE 7. - Relative importance of various buying motives in selection of screening media (2)

Buying motive	First concern	Second concern	Third concern	Fourth concern	Fifth concern
Sizing accuracy	50.00	19.23	7.69	7.69	15.39
Price	11.53	11.53	30.77	26.95	19.22
Availability	19.23	11.53	7.70	26.95	34.60
Throughput	38.46	30.77	15.39	11.53	3.85
Screen media's life	26.95	23.09	42.46	3.85	3.85

Table 8 shows the popularity of the various screening media types as reported by both *Pit and Quarry* and Twin Cities Wire Cloth. It should be noted that each surveyed plant can use more than one type of media. It is also important to note that currently only a small percentage of plants surveyed are using either rubber-coated wire cloth or perforated resilient media.

Table 9 presents a summary of the market share by manufacturer. Table 10 compares annual tonnage and cost for wire cloth. Table 11 does the same for punched plate. No data were available for rubber or urethane media. It can be summarized from the tables that the average cost per ton on punched plate is $0.0025, on woven wire cloth it is $0.0078, and $0.007 on rubber-clad punched plate.

It is easily seen why cost was not considered a major buying factor since it usually represents less than $0.01/ton. It is also easy to see why wire cloth is the most popular screening media since it gives the longest life, the highest percent open area and the necessary throughput and screening efficiency.

TABLE 8. - Percent of reporting plants using screening media types (2)

Screening media	Percent of plants
Woven Wire	93.8
Rubber coated woven wire	1.0
Plastic coated woven wire	0
Shaped (profile) wire	1.4
Perforated steel plate	18.0
Rubber on steel plate	1.6
Perforated rubber plate	9.5

TABLE 9. - Percent of market by various manufacturers (1)

Manufacturer	Perforated steel plate	Perforated rubber	Woven wire screen cloth
Abbey-Sherrer	-	-	1.6
Acme	-	-	0.6
Bacon	-	-	0.3
Burralo Wire Works	1.6	-	6.9
CF&I Steel Corporation	1.6	-	0.3
Cindaco	-	-	0.3
Cleveland Wire Cloth	-	-	0.6
Crager	-	-	0.6
Durex	-	-	7.8
Durnero	-	4.3	-
Fenway	-	-	0.3
Flint	-	-	0.6
Flynn and Enslow	-	-	1.3
Frog Switch	1.6	-	-
Harrington and King	-	-	0.3
Hendrick Manufacturing	49.2	30.5	1.3
Hewitt-Robins	1.6	-	1.6
Holz Rubber	-	4.3	-
Hoyt Wire Cloth	1.6	-	9.1
Ingrham	1.6	-	1.3
Iowa Manufacturing Company	1.6	-	8.5
Johnson and Chapman	1.6	-	-
Laubenstein Manufacturing	1.6	-	-
David Lee	-	-	0.3
Linatex	-	30.5	-
Ludlow-Saylor	1.6	-	9.4
Manganese Steel Forge	1.6	-	0.3
Meco	-	-	0.3
Midwest	-	-	1.3
Miller Brusin	1.6	-	-
Miller Wire	-	-	1.6
Monarch	1.5	-	-
Murdock	1.5	-	-
National Standard	11.1	-	-
National Wire	-	-	1.6
Pacific Wire	-	-	1.3
Pioneer Division, Portec, Inc.	4.8	-	0.9
Rey-Loy	-	-	0.3
Sherman Riley	-	-	1.9
Rubberclad	-	4.3	-
Walter Shoemacker	1.5	-	-
Simplex	-	-	0.3
Simplicity Engineering	-	-	3.8
Star Wire	-	-	4.4
Syntron	-	-	0.3
Sweco	-	-	0.3
W.B. Thompson	1.5	-	-
Trelleborg	-	21.8	-
Trinity	-	-	0.3
Twin City	-	-	3.4
W.S. Tyler Company	4.8	-	18.5
U.S. Steel	-	-	0.3
Wajax	-	4.3	-
Western Wire	1.6	-	5.9
Shop Made	3.2	-	-

TABLE 10. - A sampling of plant reported annual tonnage and costs for woven wire cloth (2)

Annual tonnage	Annual cost	Cost per ton
900,000 tons	$ 14,000.00	$0.0156
700,000	7,000.00	0.010
4,853,000	24,337.00	0.005
293,964	6,400.00	0.0218
850,000	3,000.00	0.0035
1,000,000	9,000.00	0.009
700,000	6,250.00	0.0089
16,954,000	150,000.00	0.0088
30,000	3,000.00	0.100
3,000,000	11,410.00	0.0038
500,000	3,500.00	0.007
1,477,000	12,478.00	0.0084
3,000,000	15,000.00	0.005
2,250,000	16,000.00	0.0071
200,000	11,000.00	0.055
900,000	3,500.00	0.0039
190,000	2,800.00	0.0147
300,000	3,000.00	0.010
200,000	600.00	0.003
175,000	1,100.00	0.0063
18,000	1,000.00	0.056
30,000	200.00	0.0067
660,000	2,500.00	0.0038

TABLE 11. - A sampling of plant reported annual tonnage and costs for punch plate (2)

Annual tonnage	Annual cost	Cost per ton
2,500,000 tons	$9,000.00	$0.0036
350,000	1,000.00	0.0029
3,000,000	4,951.00	0.0017
1,477,000	1,317.00	0.001
1,293,400	6,419.00	0.005
700,000	1,000.00	0.0014

2.1.4 Hoppers and Chutes

Hoppers and chutes are used for indirect discharge of multiple-deck screens, transfer points, storage and load-out facilities and many other functions. We can also classify rock boxes, bins, baffles and others in this category.

Hoppers, bins, and chutes are more often than not fabricated to suit the specific need by the operator's own personnel on the job site. The exception is when a portable plant *system* is designed by a manufacturer for a specific user. Manufacturers are usually cognizant of transfer points on a portable plant and provide for rock boxes, dead beds and wear plates. Maintenance of these components, however, is a constant problem.

Stationary plants are more prone to maintain these permanently installed items by:

a. Frequently inspecting the units for wear

b. Lining the components with abrasive-resistant materials

c. Forming dead beds for material to impact.

Portable plants are less prone to be concerned with maintenance of these items because they operate in an environment that is less sensitive to spillage, dust and noise. Repairs are often temporary and are done in the least expensive fashion. Wooden side boards, splices, temporary welding, and poor fit-up are typical of small plant operations.

2.1.5 Typical Plant Layout

Of the approximately 12,000 operating sand and gravel and crushed stone plants in the country, it is estimated that 70 percent can be termed stationary plants. The following discussion is applicable to either stationary or portable plants since comminution circuits vary little between the two types.

Figure 2 is a *typical open circuit schematic.* The size of the components will vary with the total plant capacity, but this example is indicative of a typical 200 to 250 ton/hr stationary plant producing two saleable products: 3/4 × 1/2 and 1-1/2 × 3/4 inches. Note that this operation has a +3 in. recrush stockpile that can be used to keep the secondary circuit operating in the event of the primary circuit shutdown and that the-1/2 in. material is considered waste. This typical plant represents producers of less than 150,000 tons/year and is very common.

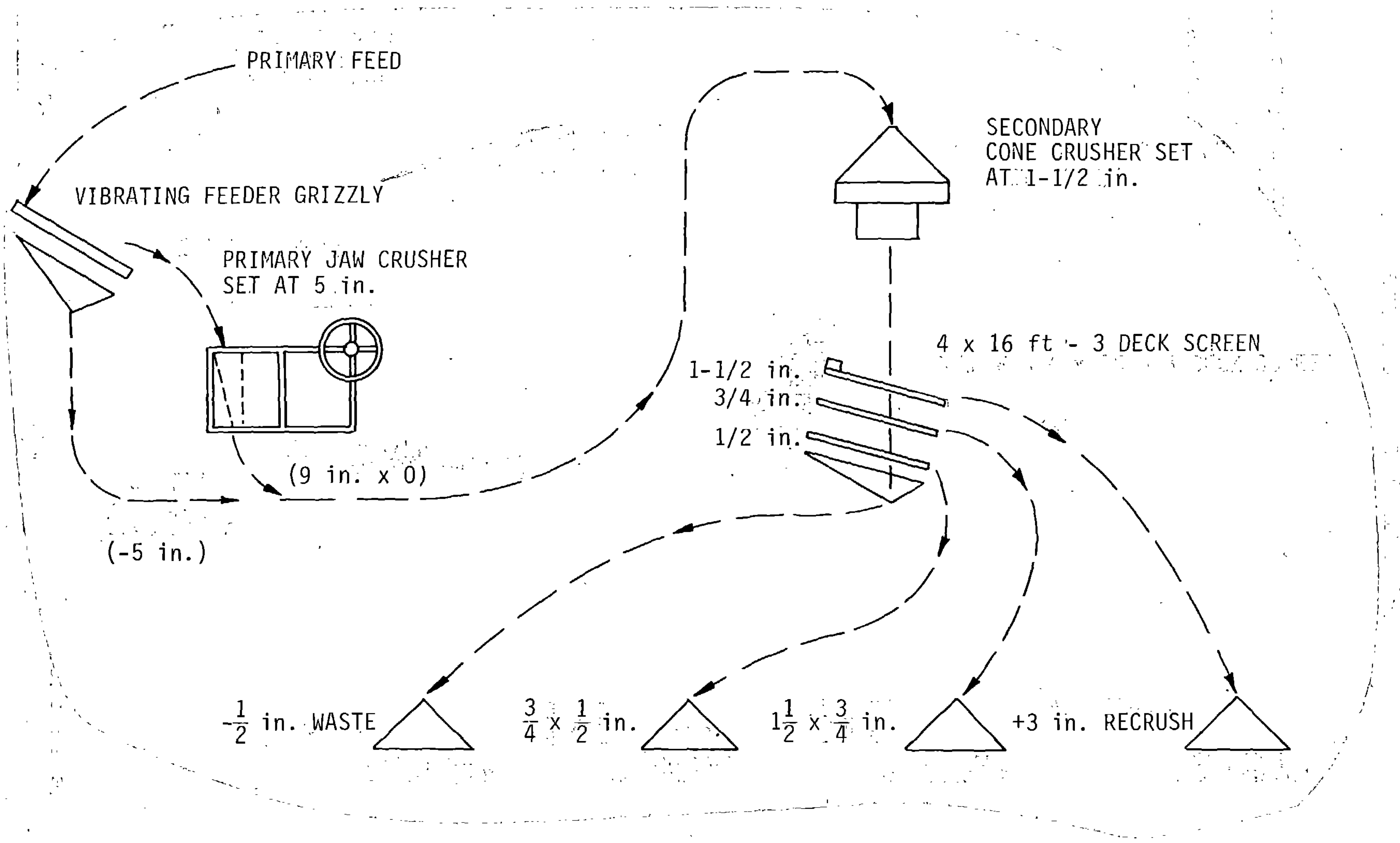


FIGURE 2. - Typical open circuit.

Figure 3 shows the addition of a tertiary crushing stage, *closed circuited* on a 1/2-in. screen. It is a modification of the same open circuit shown in Figure 2, but it has more flexibility. The addition of the third crushing and screening stage has allowed this producer to expand his market to include, for example, concrete aggregate and possibly manufacture sand by the addition of a fourth crushing stage. He no longer has a 3-in. recrush stockpile but is stockpiling after the primary stage. The 1/2 in. waste remains, but it can be used in a closed-circuit fourth stage, producing concrete sand, or if the material was suitable, agricultural lime.

2.1.6 Portable Crushing and Screening Plants

For the purposes of this program, a "portable plant" was defined as consisting of one chassis. Two chassis working together at the same location are considered two portable plants. Portable plants are further categorized as being either unitized or single chassis.

Although the Crusher and Portable Plant Association (CAPPA) does not specifically define these terms, we assume that a unitized plant has only one component, such as a screen or crusher, mounted on an individual chassis. These types of chassis represent 65 percent of the 350 to 500 portable plants sold annually. A single chassis plant has more than one component, usually a crusher and a screen, mounted on a chassis.

2.1.7 Summary

The census summary of nonmetallic portable processing plants resulted in the following typical portable plant and equipment:

a. Crushing/screening plant processing approximately 200 tons/hr from ROM to a finished saleable product

b. Primary reduction stage: 42-in. vibrating feeder grizzly and a 42 × 48 in. *maximum* jaw crusher

c. Other stages: 6 × 16-ft *maximum* triple-deck screen and a 5-1/2-ft *maximum* cone crusher.

Typically, the primary stage is remotely located and feeds other stages by conveyor from a stockpile. Other stages typically have a screen located directly over the cone crusher with oversize material fed directly to the crusher and other products chute-collected and conveyed to a stockpile or another reduction stage.

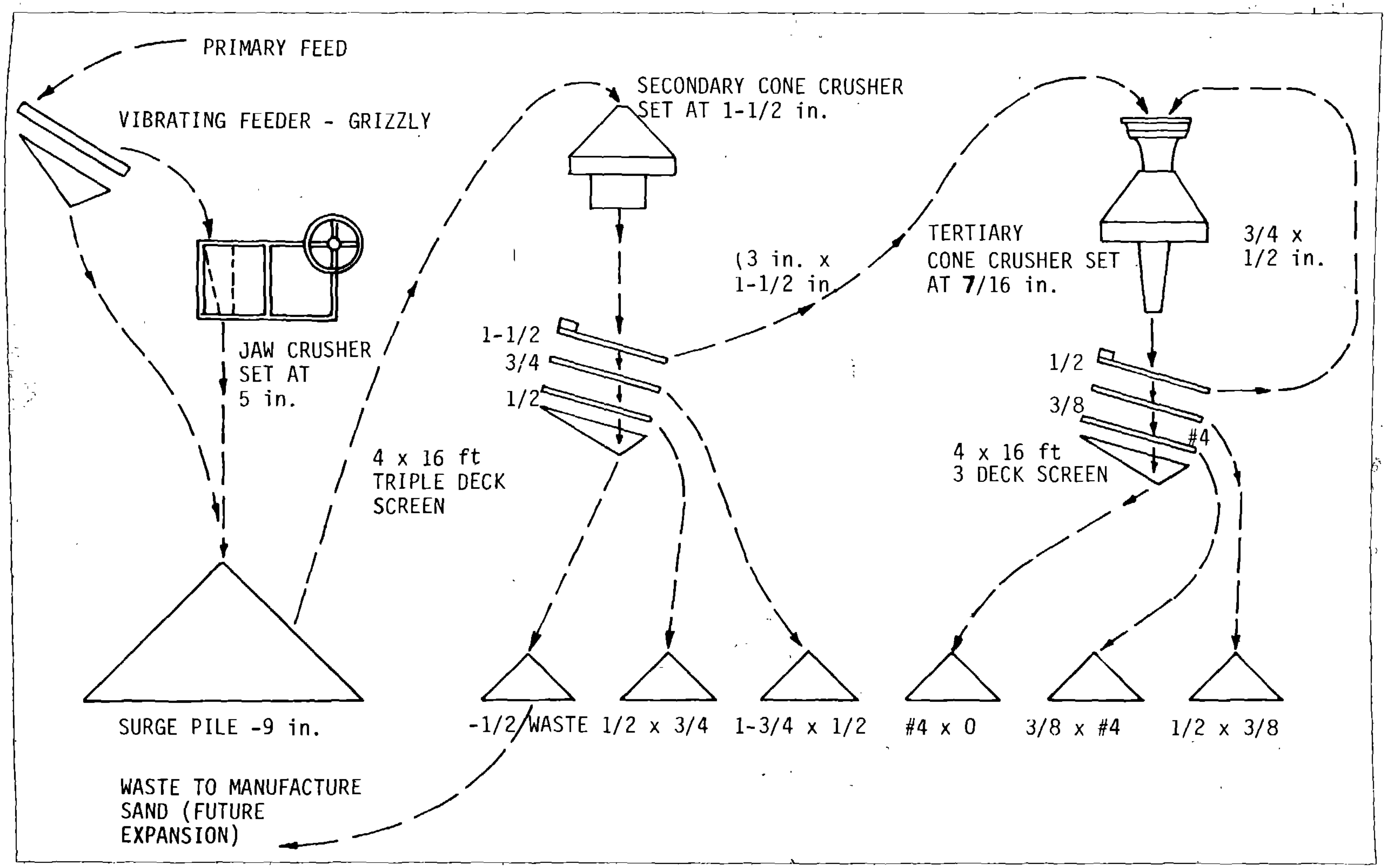


FIGURE 3. - Typical closed circuit.

2.2 Plant Selection and On-Site Visits

2.2.1 Plant Selection

The program scope and purpose and a schedule were sent early in the program to major users of the equipment determined to be typical by the industry survey. The majority of the operations were located in the South so that any weather-related program delays could be maintained. Emphasis during the initial contacts with these major producers was on visiting stationary and portable plants producing between 200 and 250 tons/hr, with the emphasis on portables. The following producers cooperated in the program:

a. Nello L Teer

b. Martin Marietta

c. Roma Stone Inc.

d. Ryder Sand and Gravel

e. Vulcan Materials

f. Wake Stone Inc.

Within these six producer organizations, eight plants were selected and visited.

Table 12 summarizes the equipment in use and the production rates for the eight selected plants. Primary stages at the plants were predominantly stationary with a jaw crusher and a vibrating feeder grizzly. Secondary stages were predominantly stationary or they consisted of a portable chassis permanently mounted to concrete pads. Cone crushers and a double-deck screen were typical for the second stage at the selected plants. Six of the eight plants had a tertiary stage. A cone crusher and triple-deck screen predominated at the tertiary stage. Final screening was performed in a quartenary stage at four of the plants with two of the plants using double-deck screens and two of the plants using triple-deck screens.

TABLE 12. - Plant survey data summary

Plant	Production rate (tons/hr)	Equipment in use					
		Primary stage	Secondary stage	Tertiary stage	Quaternary stage	Chassis	Chutes
A	200	Stationary stage Jaw crusher - 42 × 48 in. Feeder with grizzly - 16 ft × 42 in.	Portable stage Mounted permanently to concrete pads: Cone crusher - 4-1/2 ft, rubber mounted Double deck screen - 5 × 14 ft	Portable stage Short head cone crusher - 4 ft, rubber mounted	None	Portable - OEM supplied	Manufactured on site and OEM supplied
B	200	Stationary stage Jaw crusher - 32 × 42 in. Feeder with grizzly - 16 ft × 42 in.	Portable stage Mounted permanently to concrete pads: Cone crusher - 4-1/4-ft Double deck screen - 20° incline, 5 × 14 ft	Portable stage Short head cone crusher - 4 ft, Double deck screen - 20° incline, 5 × 16 ft	None	Portable - Permanently mounted on concrete OEM supplied	Manufactured on site and OEM supplied
C All stationary	500 (est.)	Jaw crusher - 42 × 48 in. Feeder with grizzly - 60 in. × 20 ft	Cone crusher - 66 in. Triple deck screen - 6 × 16 ft crusher set very coarse	Triple deck screen - 6 × 16 ft Cone crusher - 48 in.	Cone crusher - 48 in. Triple deck screen - 6 × 16 ft	Stationary foundations	Contractor manufactured and installed
D	300	Stationary stage Jaw crusher - 44 × 48 in. Feeder with grizzly - 16 ft × 42 in.	Structural steel Mounted permanently on concrete pads: Cone crusher - 5-1/2 ft Double deck screen - 6 × 16 ft	Portable stage Mounted permanently on concrete pads: Cone crusher - 5-1/2 ft Triple deck screen - 6 × 16 ft	None	Structural steel on concrete pads	OEM supplied

TABLE 12. - Plant survey data summary (continued)

Plant	Production rate (tons/hr)	Equipment in use					
		Primary stage	Secondary stage	Tertiary stage	Quaternary stage	Chassis	Chutes
E All stationary	300	Jaw crusher apron feeder - 48 in. × 16 ft	Impact crusher double deck 5 × 14 ft	Short head cone crusher - 4 ft and hammermill (4033) triple deck screen - 6 × 14 ft	Final screening - double deck screen 1.95 × 4m	Concrete support	OEM supplied
F	700	Apron feeders: 2 at 48 in. × 21 ft, jaw crushers: 1 at 32 × 40, 1 at 42 × 48	Impactor-PA18-A triple deck inclined screen: 6 × 14 ft	2 Triple deck inclined screens: 6 × 16 ft, 2 triple deck inclined screens: 8 × 20 ft, 1 standard cone crusher-4-1/4 ft, 1 short head cone crusher-4 ft	Double deck inclined screen 8 × 20 ft impactor	Concrete support	Contractor supplied and installed
G All portable	125	Diesel driven jaw crusher - 30 × 42, vibrating feeder grizzly 36 in. × 12 ft	Diesel driven cone crusher - 48 in., double deck screen - 5 × 16 ft	None	None	OEM supplied	OEM supplied
H All stationary	150	Jaw crusher - 15 × 36 in. vibrating feeder grizzly - 36 in. × 12 ft	Hydrocone crusher - 5.5 × 36 in., inclined single deck screen - 4 × 12 ft	Triple deck screen 6 × 12 ft	None	Concrete support	Field manufactured

2.2.2 Plant Surveys

The objectives of the eight plant visits were to:

a. Determine worker noise exposures that are representative of crushing and screening operations

b. Assess the nature of noise sources so that appropriate control technology could be designed

c. Identify operational and mechanical constraints at the plants which would impact noise control designs.

The following subsections summarize the results for the eight plant visits.

2.2.2.1 Worker Noise Exposures of Representative Crushing and Screening Operations

Current MSHA regulations require maintaining noise exposures to less than 90 dBA on an 8-hr time-weighted average basis. Noise dosimeters were used to monitor plant employee exposures during on-site visits to seven of the eight selected plants. Test durations ranged from 3 to 6 hr. Full-shift exposures were then projected. The projected results are summarized by employee category in Table 13.

As illustrated by Table 13, three categories of workers are potentially exposed to noise levels two to four times that allowed by current regulations. The categories are:

a. Primary operator

b. Cleanup man

c. Secondary screen operator.

Exposure variations from plant to plant for the same category of worker were considerable. This result was expected due to:

a. Wide variations in plant conditions, such as, the presence and condition of primary crusher control booth

b. Variations in how particular worker performs his duties.

Complete dosimeter test results are presented in Appendix A.

TABLE 13. - Noise dosimeter tests by plant

Worker	Percent of allowable exposure by plant[1]							
	A	B	C	D	E	F	G[2]	H
1. Plant foreman	40.8	80					-	21
2. Primary operator		325	26		51		-	188
3. Cleanup man	48			133	251	399	-	
4. Secondary screen operator			312					
Duration of tests, hrs	3.5	3	3	3	6	3.3	No tests	4.2 Foreman 3.3 Operator

[1]Projected 8 hr exposures where 100 equals the maximum allowable for an 8-hr period.

[2]No dosimeter readings taken.

2.2.2.2 Assessment of Noise Sources

A-weighted and octave band sound pressure levels were measured at all operating locations in each plant. Tape recordings were also made at each location to assist in more detailed source analysis should it be required. Measurements were also made near individual pieces of machinery so that their spectra could be used for source analysis when and if required.

Table 14 presents a summary of A-weighted sound pressure levels at operator locations in the eight plants. Noise level ranges between plants were as follows:

a. Inside main control booth - 71 to 73 dBA (two plants reporting only)

b. Inside primary crusher operator's control booth - 71 to 85 dBA

c. Outside primary crusher operator's control booth - 98 to 102 dBA

d. At secondary screen - 101 to 113 dBA

e. At secondary crusher feed - 104 to 115 dBA

f. At tertiary screen - 100 to 110 dBA

g. At tertiary crusher feed - 101 to 109 dBA.

Complete A-weighted sound pressure level data for each plant are presented in Appendix B.

The results of the survey, as expected, showed that crushers, screens, and the impacting of material on steel screen feedboxes, screen discharge lips, crusher input and discharge chutes are the major noise sources in portable and stationary crushing and screening plants. The impact of these sources on the exposure of plant personnel operating in stationary locations can be minimized with an operator control booth. The noise levels produced by these sources, however, have to be reduced to reduce the exposure of plant cleanup and maintenance personnel whose duties require them to work close to these sources.

TABLE 14. - Plant noise levels, dBA

Measurement location	Module operator area	Cleanup, maintenance area	A-weighted noise levels by plant, dBA							
			A	B	C	D	E	F	G	H
Main operating booth						N/A	N/A	N/A	N/A	N/A
Outside	x		92	94	87					
Inside	x		73	71	-					
Primary crusher										
Outside operator's booth	x		N/A	-	-	-	-	98	102[1]	-
Inside operator's booth	x		N/A	85	83	80	71	72	N/A	-
Over crusher	-	-	-	101	108	105	95	>98	>102	>100
Next to crusher discharge		x	-	-	100	-	-	-	99	-
Secondary module										
At crusher feed	-	-	>111	108	-	115	-	>104	-	110
Beside screen	-	-	112	113	106	108	113	-	109	101[2]
Base of module		x	96-98	96	-	-	99	100	103-106	92
Operator's platform	x		-	-	95[3]	-	110	94	-	93[3]
Tertiary module									N/A	N/A
At crusher feed	-	-	109	108	101	103	-	>104		
Beside screen	-	-	109	106	101	107	110	100		
Base of module		x	95	101	102	102	91	95		
Operator's platform	x		-	-	-	-	104	-		

[1] No operator's booth. Reading taken at operator's stand.
[2] Operator's area above screen.
[3] Inside booth.

Proofer ______ Typist ______

2.2.2.3 Operational and Mechanical Constraints

Designing and installing retrofit noise controls must include consideration of a variety of operational and mechanical constraints. Although each plant site presents a unique set of constraints, we can list the following as a result of the eight plant visits:

a. Operational considerations:

1. Production rate, including peak load capacity requirements.

2. Plant life

3. Market specifications, especially size

4. Cost.

b. Mechanical/maintenance considerations:

1. Plant equipment compatibility with reduction characteristics of quarried materials, that is, abrasiveness, compression strength, material moisture, friability

2. Dependable and long service life of circuit components

3. Minimum maintenance and downtime.

2.2.2.4 Plant Survey Conclusions

We can therefore conclude from the survey of eight plants that:

a. Primary crusher and scalping operators are effectively isolated from noise sources when housed in an acoustical booth

b. Secondary and tertiary operators are potentially exposed to noise levels in excess of the 90 dBA, 8-hr time-weighted average standard due to crusher and screen noise sources

c. Cleanup personnel are typically exposed to noise levels in excess of the 90 dBA standard due to exposure during cleanup operations (normally on the ground) at primary, secondary, and tertiary modules.

Phase II of the program called for designing retrofit noise control treatments for three selected portable plants. In order to select three plants, a rank-ordering of the eight surveyed plants was necessary. The rank-ordering was based on considering the production, operational, and mechanical/maintenance constraints, listed in subsection 2.2.2.3, the severity of the noise problem at each surveyed plant, and the potential cooperation from the quarry owner.

The following subsection presents a summary of the rank-ordering of the eight visited plants.

2.3 Rank-Ordering of Surveyed Plants

2.3.1 Rank-Ordering by Noise Alone

The noise rating scheme for each plant module was based on the average Noise Exposure Index (NEI), defined as:

$$NEI = \frac{C}{15} \times 2^{\frac{L - 115}{5}}$$

where

C = actual exposure time in minutes, and
L = noise level in dBA measured during the noise survey.

The exposure time was estimated from our observations at each plant and from discussions with operating personnel. The range of NEI for all plants was approximately 0 to 5. In order to be compatible with other rating criteria discussed in subsection 2.3.2, this range was expanded to 1 to 10 by simply multiplying the NEI values by 2. Ratings less than 1 were taken as 0, meaning that no noise problem existed at that module. Table 15 presents the plant modules rank ordered by the method described above.

TABLE 15. - Plants rank ordered by noise only

Rank	Plant	Noise rating
1	B - Primary crusher	9.2
2	C - Secondary screen tower	4.7
3	G - Primary crusher	4.3
4	H - Secondary module	3.7
5	D - Secondary module	3.0
6	A - Secondary module	2.8
7	A - Tertiary module	2.3
	F - Tertiary crushers and screens	2.3
8	G - Secondary module	1.9
9	E - Secondary module	1.5
10	B - Secondary module	1.3
11	B - Tertiary module	1.2
	D - Tertiary module	1.2
12	F - Secondary module	1.1
13	C - Primary crusher	0
	D - Primary crusher	0
	E - Primary crusher	0
	E - Tertiary module	0
	F - Primary crusher	0
	H - Primary crusher	0

2.3.2 Rank-Ordering By Multiple Objective Ranking Matrix

In order to make a subjective yet rational selection of plants to be noise controlled in Phases II and III of this program, other criteria were also considered. These include:

a. Size of plant (is it typical of the industry?)

b. Ease of treatment - (will available techniques make a significant impact without significant effects on plant operations?)

c. Degree of owner cooperation expected

d. Is the equipment typical of the industry?

These are discussed briefly below.

2.3.2.1 Size of Plant

In general, the larger the plant, the less desirable the plant was as a candidate for retrofit. One reason for this is that large plants with overall capacities greater than 300 tons/hr are not typical of the industry, since they represent only about 20 percent of the total number of plants. Another reason is that each individual treatment has less overall impact on a larger plant. Individual modules within any plant may have roughly the same capacity (about 150 tons/hr). But in plants with large overall capacities, the design of each module is significantly different from that in small plants. The layout of each module is different as well as its location relative to other modules. Because of these differences and because the large plants are not typical, a rating scheme which gives small plants a high score was needed. Therefore, a 1 to 10 rating scheme based on overall plant capacity was developed by fitting a straight line between 125 tons/hr and 900 tons/hr such that the latter would be a 1 on the rating scale and the former would be a 10.

2.3.2.2 Ease of Treatment

By ease of treatment we mean whether existing noise control technology available off-the-shelf can be applied to a module at reasonable cost with maximum impact and without adversely affecting production. Each plant module was assessed according to this criterion and given a 1 to 10 rating which was used in the multiple objective ranking matrix.

2.3.2.3 Degree of Owner Cooperation

Cooperation and assistance from plant owners was of course essential for program success. Without the interest and support of the owner no treatments could be installed. Based on discussions between the various owners and Foster-Miller engineering personnel, the degree of expected cooperation was assessed and given a 1 to 10 rating. This rating was then entered into the ranking matrix.

2.3.2.4 Is the Equipment Typical of the Industry?

The intent of this program was to demonstrate the use of off-the-shelf noise control technology in crushing and screening plants which can be applied extensively throughout the industry, thereby significantly reducing noise problems. The treatment of unusual pieces of equipment, not typical of the majority of plants across the country, was clearly not consistent with this purpose. This criteria was addressed to some extent by unfavorably weighting very large plants as discussed in subsection 2.3.2.1. To be sure that such nontypical equipment was eliminated from consideration in small plants as well, each module in each plant was given a 1 to 10 rating based on whether its design was typical of industry practice.

2.3.2.5 Multiple Objective Ranking Matrix

Each of the five evaluation criteria was given a weighting factor based on its importance in the selection process. Severity of noise and whether a plant was typical of the industry were considered the most important and therefore were given a weighting of 1. The other three criteria (plant size, ease of treatment, and owner cooperation) were considered only slightly less important and were therefore given a weighting of 0.9.

Table 16 shows the multiple objective ranking matrix, and Table 17 gives the rank-ordering of plants which resulted. In order to make final recommendations for plants to be retrofitted still other factors had to be considered. These are discussed below.

2.3.2.6 Conclusions

A choice had to be made from among the top rank ordered plants for retrofit during Phases II and III that complied with program objectives and yet remained within the current program scope. Many problems had been noted during Phase I that are

TABLE 16. - Multiple objective ranking matrix

	Severity of noise problem	Size of plant	Ease of treatment	Degree of owner cooperation	Typical of industry	Score
			Weighting factor			
Plant/module	1.0	0.9	0.9	0.9	1.0	
Plant A						
Secondary module	2.8	8.7	6.3	9.0	10.0	36.8
Tertiary module	2.3	8.7	6.3	9.0	10.0	36.3
Plant B						
Primary crusher	9.2	8.7	4.5	9.0	8.0	39.4
Secondary module	1.3	8.7	6.3	9.0	8.0	33.3
Tertiary module	1.2	8.7	5.4	9.0	8.0	32.3
Plant C						
Primary crusher	0	5.1	0	5.4	10.0	20.5
Secondary screen tower	4.7	5.1	4.5	5.4	5.0	24.7
Plant D						
Primary crusher	0	8.2	0	6.3	10.0	24.5
Secondary module	3.0	8.2	7.2	6.3	7.0	31.7
Tertiary module	1.2	8.2	7.2	6.3	5.0	27.9
Plant E						
Primary crusher	0	7.2	0	3.6	8.0	18.8
Secondary module	1.5	7.2	1.8	3.6	5.0	19.1
Tertiary module	0	7.2	4.5	3.6	7.0	22.3
Plant F						
Primary crusher	0	3.1	0	1.8	2.0	6.9
Secondary module	1.1	3.1	2.7	1.8	5.0	13.7
Tertiary crushers and screens	2.3	3.1	0.9	1.8	4.0	12.1
Plant G						
Primary crusher	4.3	8.7	8.1	7.2	10.0	38.3
Secondary module	1.9	8.7	6.3	7.2	10.0	34.1
Plant H						
Primary crusher	0	9.0	8.1	8.1	6.0	31.2
Secondary module	3.7	9.0	7.2	8.1	9.0	37.0

TABLE 17. - Plants rank ordered by multiple objective ranking matrix

Rank	Plant	Score
1	B - Primary crusher	39.4*
2	G - Primary crusher	38.3
3	H - Secondary module	37.0
4	A - Secondary module	36.8*
5	A - Tertiary module	36.3
6	G - Secondary module	34.1
7	B - Secondary module	33.3*
8	B - Tertiary module	32.3
9	D - Secondary module	31.7*
10	H - Primary crusher	31.2
11	D - Tertiary module	27.9
12	C - Secondary screen tower	24.7
13	D - Primary crusher	24.5
14	E - Tertiary module	22.3
15	C - Primary crusher	20.5
16	E - Secondary module	19.1
17	E - Primary crusher	18.8
18	F - Secondary module	13.7
19	F - Tertiary crushers and screens	12.1
20	F - Primary crusher	6.9

*Recommended for retrofit.

attendant to the noise problem and can be addressed by technology and good operating practices. Noise can be attenuated in the plants visited by proper maintenance, good process circuit design, use of engineering controls, and noise attenuating hardware.

Four of the operations ranked in the top 10 shown in Table 17 were recommended as candidates for retrofit. Each provided a unique problem to be addressed by available techniques. Although specific recommendations were not made to the owners of these plants, it was assumed that they would continue to cooperate. Plants G and H were excluded because of possible climate problems during the retrofit. The following plants or areas of a plant were Foster-Miller's suggested candidates:

Plant B

Primary crusher - A new booth was recommended for this high exposure area. A recommendation was made to reinforce the superstructure, and the plant owner agreed to this safety step. Not only was the noise problem addressed by the recommendation, but operating procedure and control locations were also addressed.

Secondary module - This semi-portable plant has an *inclined* screen that is fully loaded. The effect of resilient cloth on noise attenuation and screening efficiency was recommended for evaluation. The other components of the module are typical and offered a good source for evaluation of controls.

Plant A

Portable secondary module - This installation uses a *horizontal* screen fully loaded and again provides a good test for resilient cloth noise control and efficiency testing. This plant is very typical of portables and many attendant problems could be studied and changes effected. Plant management was exceptionally cooperative.

Plant D

Secondary module - This stationary plant is also representative of the industry. Crusher feed noise problems were the main areas to address. The stationary inclined screen could also be retrofitted. Plant management is representative of large producers and initially seemed anxious to cooperate in the retrofit program. This cooperation was later withdrawn because of interest conflicts.

2.4 References

1. "Marketing Study of Types, Brands, and Purchasing Plans for Crushers, Screens, Screening Media in the Construction Aggregates Industries," *Pit and Quarry*, 105 West Adams Street, Chicago, IL 60603, 1974.

2. Fischer, James A., "Screening Leaders," *Pit and Quarry*, September, 1979, pp. 55-58.

3. RETROFIT NOISE CONTROL DESIGN

3.1 Final Site Selections

The ranking criteria described in subsection 2.3 identified three modules as prime candidate test sites. The three modules, located at Plants A and B, are owned by a single company. Both plants are located in the South approximately 40 mi apart, and they are easily accessible. Final selection of these two plants enabled the program to:

a. Retrofit a 200 to 250 ton/hr portable cone crusher plant with a horizontal vibrating screen

b. Retrofit a portable cone crusher plant with an inclined screen

c. Retrofit a primary jaw crusher installation.

3.2 Preliminary Design

Data collected during the Phase I survey were reviewed for each module to be retrofitted. Special attention was given to the required noise exposure reduction, the major sources of noise, previous attempts by the plant to reduce noise and operational, mechanical and physical constraints involved at each module.

Publications by MSHA documenting past efforts by the mining industry were also reviewed. The TPO furnished USBM reports to Foster-Miller on work done in controlling vibrating screen noise and noise in coal and taconite plants. Data were solicited and reviewed from manufacturers of resilient and acoustical materials to assist in the design process for retrofitting the modules. Emphasis was placed on barrier materials, operator enclosures and the use of resilient materials. Consideration was given to the following ways to bring the exposure of operating personnel of each module into compliance:

a. Eliminate the noise source - changes in material flow

b. Isolate the noise source from the operator - enclose the noise source

c. Isolate the man from the noise source - control booth

d. Reduce the noise emissions - install resilient linings, modify the material handling or flow, utilize maintenance procedures.

As required by the contract, the retrofit treatment was to meet the following design criteria:

a. Treatment must be acoustically effective

b. Only commercially available materials were to be used

c. No special services or facilities should be required to fabricate, install and maintain the treatment

d. Treatment must be durable and cost-effective

e. Treatment must have a minimal impact on the plant/ module operation.

Figure 4 schematically shows the potential areas of a typical portable plant that contribute to the operating noise level. The preliminary design considerations included a subjective evaluation of the noise contribution of each point.

3.2.1 Plant B - Primary Crusher Installation

The initial noise survey showed that the jaw crusher operator was exposed to 101 dBA at his normal work position on the catwalk over the feeder. Data extrapolated from a 3-hr dosimeter survey indicated that the operator exceeded 325 percent of the allowable noise exposure.

The major sources of noise in the area included:

a. Quarry trucks and/or front end loaders dumping material into the feed hopper

b. Material being conveyed and sized on the feeder/grizzly

c. Material falling into and being crushed by the jaw crusher

d. Warning alarms to signal start-up and no-dump situations.

Previous attempts to reduce the operator's exposure had limited effect. A control booth had been constructed at the station. Noise level readings measured in the booth were 85 dBA.

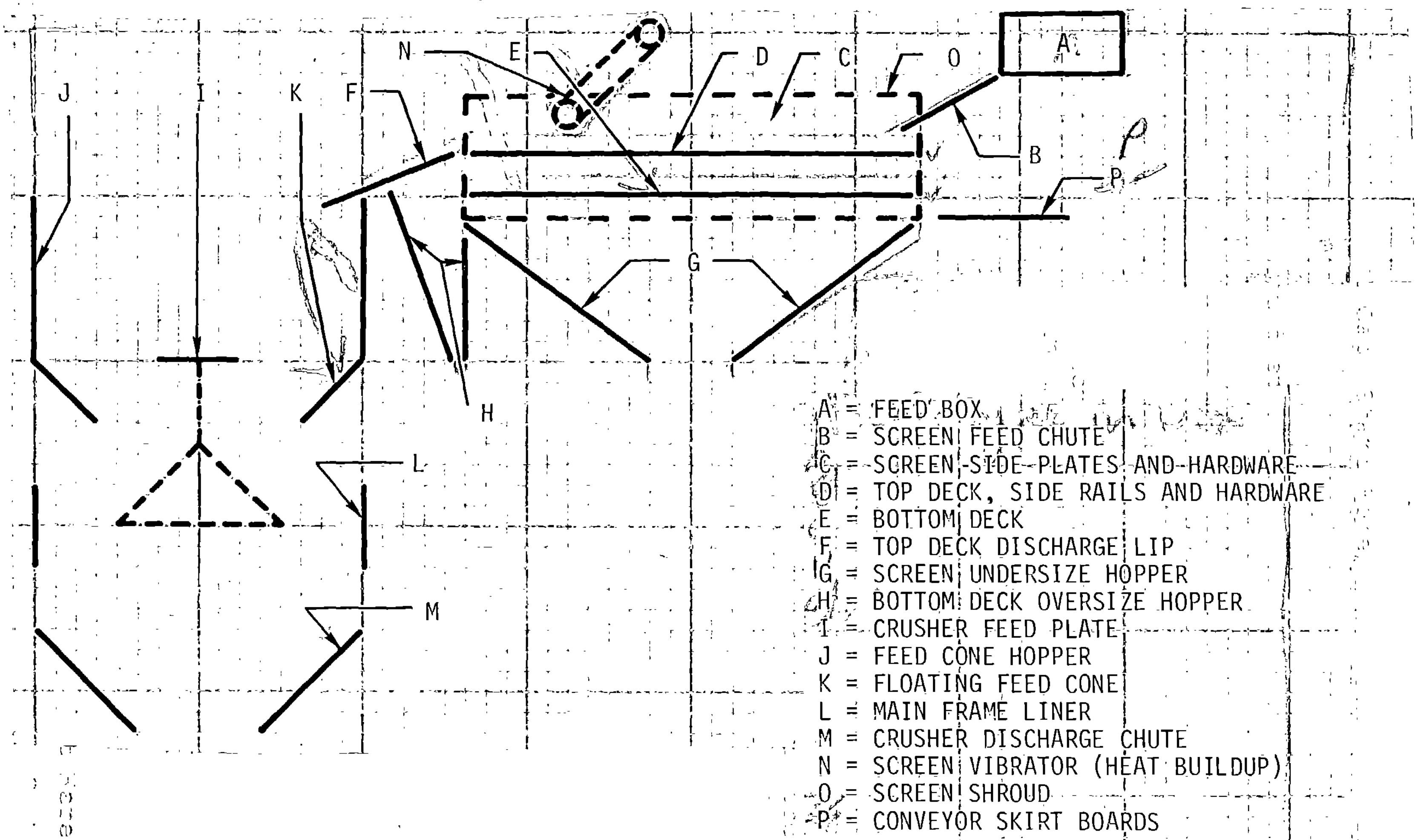


FIGURE 4. - Potential attenuation points - portable crushing plant.

The operator, however, chose to leave the control room door open because the booth was small, hot, and impaired his vision. Since the sources of the noise could not be eliminated or effectively minimized, an acoustically effective control booth was recommended.

The following design criteria were agreed upon:

a. Reduce inside booth noise level to 80 dBA

b. Provide adequate visibility for operator to perform his duties from inside the booth

c. Climatize the booth for the operator's comfort.

These design objectives would encourage the operator to remain inside the control booth with the door closed during his work shift.

3.2.2 Plant B - Secondary Module

The inclined screen/cone crusher secondary portable plant, Plant B, provided the opportunity to address the problem of coarse run-of-mine (ROM) precrushed material being screened and further sized in a secondary crusher. The coarse feed to the plant, -10 in., is conveyor belt-fed to a screen feedbox, accelerated over a 20-deg double-deck inclined screen, discharged into a crusher feedbox, crushed in a cone crusher, and finally discharged from the plant on a transfer belt.

General design considerations included:

a. Minimize impact noise at the screen feedbox discharge lip

b. Attenuate noise from the screen top deck

c. Minimize impact noise at the screen discharge lip

d. Reduce impact noise at the crusher feedbox

e. Minimize impact noise from the crusher feed plate area

f. Reduce impact noise from the screen top deck wings.

Since this plant is not production-sensitive, these goals were realistic. Effective screening takes place within the first one-third of the screen feed end and the top deck throughs and the second deck overs are closed on the crusher feed. The crusher is not overloaded. The major problem to be addressed outside of noise control would be the random impact of large, accelerated pieces of material with the machine elements. These noise sources could be treated with acoustically effective material, but the life of the material in service would be variable and cost-sensitive.

3.2.3 Plant A - Secondary Module

The horizontal double-deck screen/cone crusher secondary module, Plant A, offered the opportunity to retrofit an equally popular portable plant. This plant also receives a precrushed and stockpiled ROM -10 in. material. Although this plant is fed in a similar manner to Plant B, the feed contains more coarse material and the material is not accelerated over the screen except by the screen throw itself. The plant feed is discharged into a feedbox, drops to the integral screen feedbox, travels across the screen in a relatively uniform manner, discharges into a cone crusher, and is finally crusher-discharged onto a transfer belt.

General design considerations agreed upon include:

a. Minimize impact noise at the screen feedbox

b. Attenuate noise from the screen top deck

c. Reduce impact noise at the screen discharge lip

d. Reduce impact noise at the crusher feed.

These points were the major sources of noise contributing to the noise problem. Maintenance and clean-up work around the base of the plant must be done close to these sources.

3.3 Follow-Up Plant Visits

During this task, FMA revisited the three plants for the following purposes:

a. To establish a noise level data base against which the retrofit treatment could be measured

b. To determine plant production sensitivity to potential retrofit treatments

c. To familiarize vendors of resilient materials with the noise and production problems of these plants and evaluate the vendors' capability to meet the program goals

d. To take dimensions of plant elements requiring treatment.

These activities are summarized in the following subsections.

3.3.1 Plant B - Primary Crusher Follow-Up Visit

The jaw crusher operator's extrapolated full-shift exposure measured in Phase I indicated an overexposure of 325 percent. Table 18 shows sound level meter readings taken during the follow-up visit.

A review of the operator's work habits and environment reinforced Foster-Miller's conclusion that the operator must be insulated from the noise sources in order to reduce his exposure. The sources themselves were too numerous and variable to reduce individually in a cost-effective manner.

3.3.2 Plant B - Inclined Screen Plant Follow-Up Visit

Table 19 shows noise data taken at the portable screen/secondary crusher plant during the follow-up visit. The following areas were identified as the major noise sources:

a. Feedbox discharge lip

b. Screen top deck

c. Screen discharge lip

d. Crusher feedbox

e. Crusher feed plate

f. Screen top deck wings.

The screen and crusher throughs discharge into rock boxes. The transition area from the feedbox to the screen and from the screen to the plant discharge conveyors varies depending on the amount of fines in the material being transferred. None of these transition points are as significant as the primary sources mentioned above. All pertinent dimensions were recorded for use in final design preparation.

The plant is not production-sensitive when processing ROM or a blended ROM with sand. Retrofit treatment would not affect the screen or crusher capacity if the bottom deck screen cloth size,

Proofer ________ Typist ________

TABLE 18. - Plant B - jaw crusher operator sound level readings

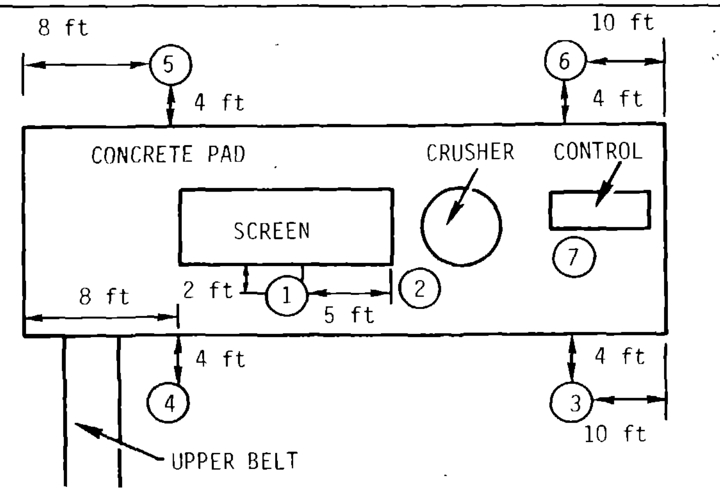
Measurement Location	Sound Pressure Levels										
	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
Inside primary crusher booth-door closed	84	91	87	82	80	76	73	69	64	51	45
Inside booth-door open	85	86	89	90	85	86	83	77	70	60	52
At primary crusher	97	86	100	94	98	97	90	82	72	67	64

TABLE 19. - Plant B noise data base

Measurement Location	Sound Pressure Levels										
	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
1. At secondary screen 2 ft from side plate 5 ft from discharge	106-108	83	91	93	96	100	100	102	97	88	87
2. At crusher feed 2 ft from hopper fifth step from top	112	83	86	97	103	108	108	107	99	90	80
3. Ground level	93	84	83	84	88	87	88	85	78	70	62
4. Ground level	97	83	86	89	90	92	94	91	84	75	66
5. Ground level	96	82	83	87	90	91	93	89	82	73	65
6. Ground level	96	82	82	87	89	90	91	87	82	72	63
7. At control panel 7 ft from motor (crusher) 2 ft from panel	94	81	86	89	90	92	90	87	81	72	63

Sketches, comments and notes

All measurements taken at waist level before retrofit.



1-1/4 in., was not altered. The crusher sees all +1-1/4 in. feed from the stock pile and is not drawing a maximum of 150 hp. All screening is done in the first third of the top deck. The screen was acting as an oversize chute and would not be overloaded by the use of resilient cloth on both decks if the percentage of open area were reduced.

3.3.3 Plant A - Horizontal Screen Plant Follow-Up Visit

Table 20 shows noise data taken at Plant A during the follow-up visit. The major noise sources included:

a. Screen feedbox

b. Screen top deck

c. Screen discharge lip

d. Crusher feed plate

e. Crusher feed cone.

Dead beds formed by the screen discharge chute construction appeared to be effective, as were the rock boxes below the crusher. The crusher discharge conveyor did not seem to be a major noise source.

This plant was not production-sensitive in that the top and bottom decks normally discharge into the crusher; the top deck being 3-in. diam plate and the second deck 1-1/4 in. wire cloth. The crusher and screen top deck were fully loaded, but the plant was sensitive to only +1-1/4 in. material. No retrofit treatment would retain more +1-1/4 in. material than was being currently retained.

3.4 Retrofit Material Selection

Manufacturers of components made of resilient materials and acoustical materials were contacted by a general letter early in Phase II. The scope of the program was outlined to these companies as well as the extent that they would have to participate in the program if they were selected. Major requests included:

a. Meet with Foster-Miller at plants

b. Meet with plant owner to discuss specifics of retrofit

c. Assist Foster-Miller and plant in installing components

d. Backup products being installed.

TABLE 20. - Plant A noise data base

Measurement Location	Sound Pressure Levels										
	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
1. Ground level 3 ft from belt 6 ft from plant	98	84	88	92	93	95	94	94	88	76	68
2. Ground level clean-up areas	99	84	87	91	92	95	95	94	88	76	68
3. Ground level	96	84	86	91	92	92	91	89	83	72	61
4. Ground level	94	80	86	88	89	91	90	86	77	66	52
5. At crusher 2 ft from crusher 4 ft from rail	109	82	92	96	100	104	105	102	96	85	73
6. At screen 2 ft from discharge lip	113	92	92	95	102	107	108	108	104	92	82

Sketches, comments and notes

All measurements taken at approximately waist level.

These measurements are before retrofit.

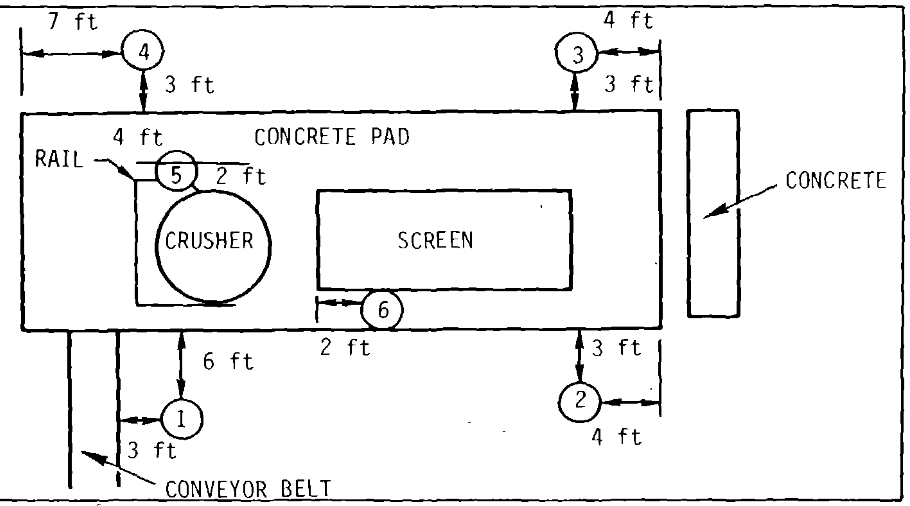


Table 21 is a matrix developed to help evaluate the capabilities of these vendors, since not all could be met at the sites. Primary considerations in this evaluation included:

a. Willingness to participate as outlined above

b. Background in the minerals industry, especially screening of metal/nonmetal minerals

c. Influence in the marketplace

d. Capability to supply the potentially wide range of products for a complete plant

e. Background knowledge of noise attenuation through the use of their products.

Durex, Hewitt-Robins and Trelleborg were selected as being the most capable to meet the program needs.

During the follow-up visits, these suppliers were provided the opportunity to examine the two plants. The program team agreed that one supplier should treat Plant A and another treat Plant B so that a commitment to success was more assured. The suppliers were informed of this tactic during their plant visits. These suppliers were observed for their knowledge in noise control, material handling, crushing and screening and thoroughness in dimensioning equipment for future installation of their products. Their questions regarding these plants often reflected their capabilities to follow through on the goals of the program.

It became obvious to Foster-Miller during the plant visits and quote evaluation that noise control *per se*, by using resilient materials, was an art employed by manufacturers and users as an afterthought more than by design. Commercially-available resilient materials used for screen cloth and chute linings are formulated for their physical properties relating to their utility and durability rather than noise control, and a wide selection is not available.

The manufacturers were reluctant to estimate the noise reduction potential if their products were used. Their quotations addressed areas of the modules where they could make use of existing product molds or could readily make them. Noise reduction estimates, when made, were based on laboratory data for samples

TABLE 21. - Resilient material manufacturers

Considerations for Program Application	B.F. Goodrich	Durex	EAR	Hendrix Mfg. Co.	Hewitt-Robins	Skega	Trelle-borg	W.S. Tyler
	Company Contacted							
I. General								
Exhibited interest in program	E	E	E	E	E	P	E	P
Previous noise control experience	F	F	G	F	F	G	G	P
U.S.A. manufactured	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
II. Resilient Screen Cloth								
Rubber	Yes	No	NA	Yes	No	Yes	Yes	No
Urethane	No	Yes	NA	No	Yes	No	Yes	Yes
Steel backed	No	No	NA	Yes	Yes	U	Yes	No
Wire reinforced	No	Yes	NA	No	No	U	Yes	Yes
Previous screening experience	F	G	NA	E	G	G	G	E
Has delamination been a problem	No	No	NA	Yes	Yes	No	No	No
Are openings tapered	Yes	Yes	NA	Yes	Yes	Yes	Yes	Yes
Is modification to screen deck support necessary	U	No	NA	No	No	Yes	No	Yes
III. Resilient Liners								
Rubber	Yes	No	Yes	NA	No	Yes	Yes	NA
Urethane	No	Yes	No	NA	Yes	U	Yes	NA
Variety of attachment methods	Yes	Yes	Yes	NA	Yes	Yes	Yes	NA
Profiled liners	Yes	No	No	NA	No	Yes	Yes	NA
Noise curtains	No	No	Yes	NA	No	No	Yes	NA
Manufacture crusher feed plate liners	No	No	No	NA	No	U	Yes	NA
Manufacture trowellable urethane	U	Yes	No	NA	Yes	U	No	NA

KEY: E - excellent; G - good; F - fair; P - poor; NA - not applicable (does not manufacture); and U - unknown.

trowellable

Proofer

Typist

run under controlled conditions, or data taken on a single machine, i.e. screen, under some control. Sales terms such as "virtually eliminates noise..., reduced noise..., quiet..., etc." were subjectively used to recommend one material over another. No unique application of material or new material was suggested.

The quoted costs for just the resilient material varied from $9,000 to $16,000 for a portable plant. Some of the required retrofit procedures involved extensive drilling, torch cutting and assembly time in the field. If these procedures were to be incorporated into the program (assuming that they were necessary and successful), the retrofit cost for a module could go as high as $20,000. This represents approximately 10 percent of the purchase price of a new 125 to 175 ton/hr secondary cone crusher/ screening plant. Foster-Miller felt that such a high percentage of the original cost of the plant would make a retrofit program unattractive to the industry and that the large use of resilient materials for noise attenuation would prevent the program goals from being achieved.

Benefits of resilient materials must include a substantial increase in material life and a subsequent savings in downtime (lost production) and maintenance labor to justify this much additional cost to a plant. Some of the manufacturers, specifically Trelleborg, offer warranties when their material is used. Trelleborg guarantees that their screen cloth will outwear the customer's previous metal cloth by the ratio of the increased cost, and that the savings in downtime and labor are the users' bonus. Estimates for noise reduction are not sold as a benefit.

Table 22 is a tabulation of cost estimates, submitted by three manufacturers, for materials in a specific area of the program's portable plants. Foster-Miller felt that if all of these areas were addressed in the suggested manner and for these costs, the subsequent program technology transfer would not be adequate.

All of the manufacturers who quoted were equally knowledgeable in screening, material handling and noise control. However, it is not unfair to observe that primarily they wanted to sell wear-resistant materials to the industry; the noise attenuation of the material is a secondary concern.

Foster-Miller recommended that Trelleborg be selected to completely retrofit Plant B with the inclined screen, to the design specifications of Foster-Miller. All of the manufacturers who observed this operation agreed that the life of the resilient material will be dependent on the size and velocity of the rock

TABLE 22. - Initial cost estimate

Potential Noise Attenuation Point	Plant A			Plant B		
	Trelleborg	Durex	Hewitt-Robins	Trelleborg	Durex	Hewitt-Robins
Feed box	$ 4,684	$ 708	$ 1,408	$ 1,169	$ 354	-
Screen feed chute	843	-	320	-	-	-
Screen side plates	-	-	792	647	-	792
Top screen deck	7,977	5,484	4,693	7,524	5,200	5,536
Bottom screen deck	-	-	2,980	-	-	2,980
Discharge lip	643	660	1,960	429	-	600
Crusher feed plate	440	-	325	-	-	-
Feed cone hopper	793	1,800	-	-	600	-
Floating feed cone	-	-	-	-	-	196
Crusher enclosure	591	-	452	4,300+	600	1,160+
Conveyor skirt board	-	70	460	-	-	-
Other points	-	-	-	-	-	-
Total	$15,971	$8,722	$13,390	$14,069	$6,754	$11,264

being processed. They all agreed that only the properties of rubber could survive in this application. Both Durex and Hewitt-Robins were hesitant to quote urethane products for this application and did so only to be responsive.

Durex was recommended to retrofit Plant A with their urethane materials. Durex was no more knowledgeable in the application of their material to this plant than Hewitt-Robins, but they offered a more practical approach in the use of *generic* urethane materials. Durex does not make proprietary products for use in the industry, but rather incorporates Uniroyal and Dupont elastomers, as do other resilient material manufacturers. FMA felt that, initially, more data could be obtained by using materials in common use in the industry in a more practical design fashion.

3.5 Final Design, Fabrication, and Installation

3.5.1 Plant B - Primary Crusher

As discussed, the primary sources of noise for the operation of the primary crusher at Plant B could not be reduced in a cost-effective manner. A control booth for the operator, therefore, was recommended.

The booth was designed to:

a. Result in noise levels inside the booth of approximately 80 dBA

b. Provide adequate visibility for the operator to perform his control duties from inside the booth with all doors and windows closed

c. Provide a comfortable environment year-round so that the operator stays inside the booth when the plant is operating.

The booth design specifications are shown in Table 23 with the original estimates for both material and labor costs.

The wall construction detail is shown in Figure 5. As shown, the basic construction uses 2 × 3-in. studs with 5/8-in. sheetrock on the outside covered with aluminum siding. The inside walls are 5/32-in. wood paneling over a double layered gypsum wallboard (1/2-in. and 5/8-in.). Wall cavities were insulated with 2-1/4-in. fiberglass (R-11). The fiberglass was installed against the outside wall leaving a 1/2-in. airgap between the fiberglass and the interior wall.

TABLE 23. - Control booth material and labor estimate

	Material and Installation Cost	Amount Needed	Price
WALLS			
1/2 in. gypsum board	\$0.26/ft^2	200 ft^2	\$ 52.00
5/8 in. gypsum board	0.33/ft^2	200 ft^2	66.00
5/32 in. panelling	0.65/ft^2	200 ft^2	130.00
5/8 in. sheet rock	0.91/ft^2	200 ft^2	182.00
R11 insulation	0.35/ft^2	288 ft^2	101.00
CEILING			
3/8 in. prefinished sheet rock	0.68/ft^2	80 ft^2	54.00
suspended ceiling panels	0.97/ft^2	80 ft^2	78.00
30 galvanized steel	0.78/ft^2	80 ft^2	62.00
R14 insulation	0.50/ft^2	80 ft^2	40.00
FLOOR			
5/8 in. fir (plywood)	0.85/ft^2	80 ft^2	68.00
1/16 V.A. floor tile	0.57/ft^2	80 ft^2	46.00
R7 insulation	0.29/ft^2	80 ft^2	23.00
WINDOWS			
48 × 24 fixed pane, laminated windows	300.00	3	900.00*
HVAC			
7000 Btu heater and ac thermostat controlled	600.00	1	600.00
LIGHTING & ELECTRIC			
60A main breaker	166.00	1	166.00
110V auplex	5.31	6	32.00
copper Romex raceway	0.60/ft	100 ft	60.00
5S24U fluorescent lights	57.15	2	114.00
FRAME			
2 × 6 in. beams (floor)	3.80	8	30.00
2 × 3 in. beams (ceiling and wall)	3.40	34	116.00
Installation - 2 carpenters and power tools	236/day	3 days	708.00
DOORS			
36 × 80 in. insulated aluminum (300 ea) acoustically made	300.00	2	600.00*
36 × 80 in. insulated aluminum door, half window (24 × 36 in.) acoustically made	400.00	1	400.00*
Total cost for booth			\$4,628.00

* Prices based on quotes received from vendor.

30,00
116,00

Proofer ____________ Typist ____________

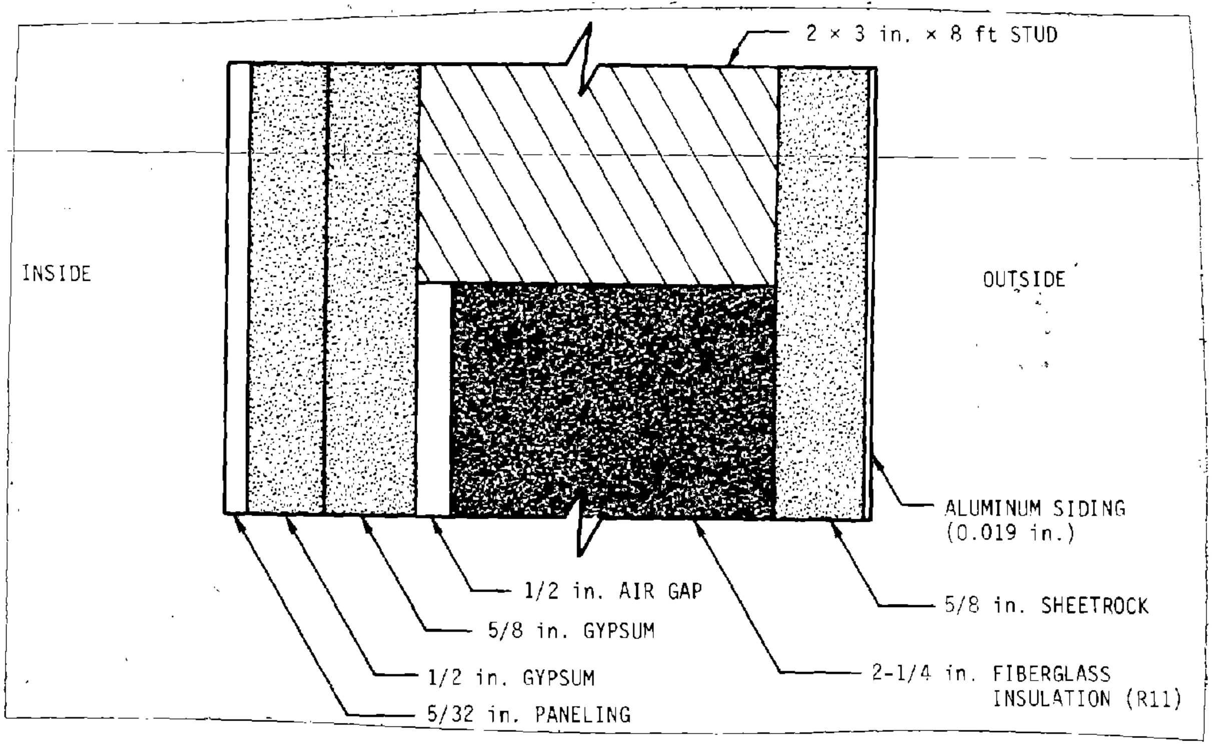


FIGURE 5. - Control booth wall construction.

The final design of the 8 × 10-ft booth is shown in Figure 6. The windows were sliding, double-pane construction with a 3/4-in. airgap. Environmental control was achieved with a 13,800 Btu air conditioner and two, 4-ft long electric baseboard heaters rated at 2 kW.

The control booth was fabricated by Design Space International, Bala Cynwyd, PA, and is commercially available from its numerous distributors throughout the country. This booth could also be constructed by any quarry operator using a minimum of skilled labor. For this program, Foster-Miller purchased the completed booth.

The original control booth was mounted directly on the crusher support structure. Original plans for mounting the new booth called for isolating the booth using rubber isolators between the crusher frame and booth floor. Isolation was required to minimize the transmission of vibration from the crusher support structure into the booth structure. Further considerations, particularly operator safety, led Foster-Miller and the quarry owner to the decision that a separate support structure for the

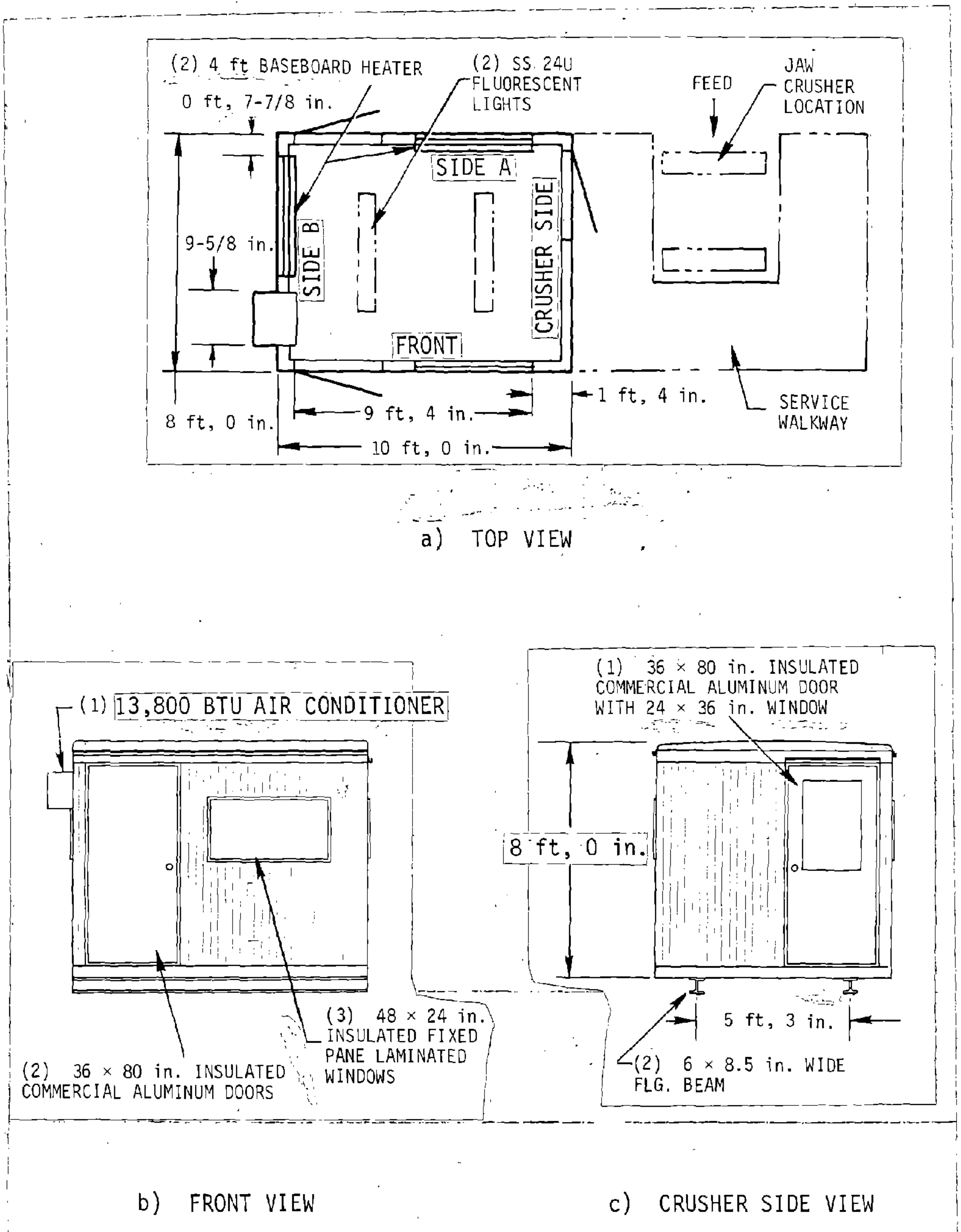
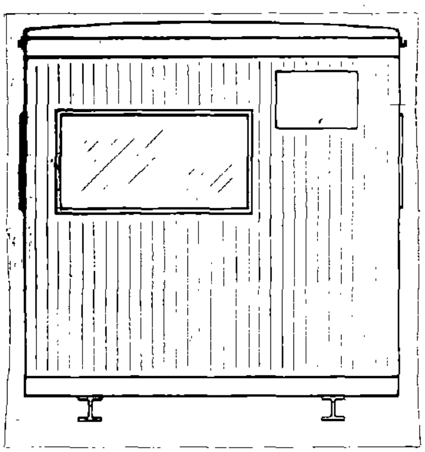


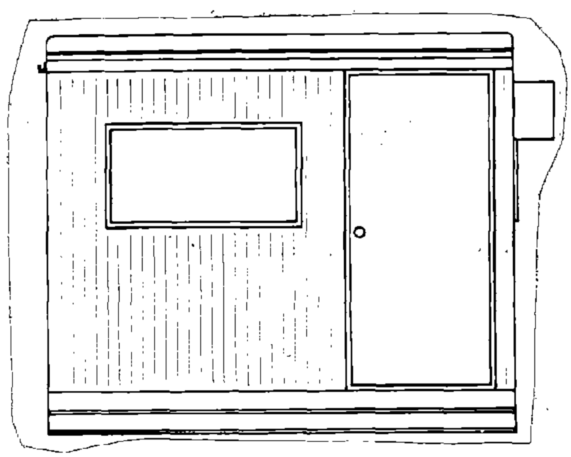
FIGURE 6. - Operator's control booth.

ELECTRIC	
LOAD CENTER:	(1) 60A WITH MAIN BREAKER
RECEPTACLES:	(10) 110V AUPLEX
RACE WAY:	COPPER ROMEX
FRAME	
FRAME:	6 in.
FLOOR	
JOIST:	2 × 6 × 8 ft, 16 in. O.C.
SUB FLOOR:	5/8 in. FIR
COVERING:	1/16 in. V.A. FLOOR TILE
INSULATION:	R7
INTERNAL AND EXTERNAL WALLS	
STUDS:	2 × 3 × 8 ft B.O.C.A.
PANELING:	5/32 in. WOODGRAIN MUSKET
INSULATION:	R11
SPECIAL:	1/2 in. GYPSUM OVER 5/8 in. GYPSUM
EXT. SIDING:	0.019 in. ALUMINUM OVER 5/8 in. GYPSUM
EXT. TRIM:	0.019 in. ALUMINUM
ROOF	
CEILING PANEL:	SHEETROCK PANEL, PREFINISHED, 3/8 in.
INSULATION:	R14
ROOFING:	30 GA. GALVANIZED STEEL

d) CONTROL BOOTH GENERAL SPECIFICATIONS



e) SIDE B VIEW



f) SIDE A VIEW

FIGURE 6. - Operator's control booth (continued).

booth was warranted. The support structure was constructed on-site by quarry personnel using 6-in. I beams. The structure is completely independent of the crusher support frame. The booth (Figure 7) was then mounted on the support structure so the operator could step directly from the booth onto the catwalk over the crusher throat.

The following costs are based on actual purchase prices and the use of quarry personnel to install the booth:

a. Booth cost = $4919 delivered ($291 delivery charge).

b. Installation time = 40 manhours.

3.5.2 Plant B - Inclined Screen/Cone Crusher Plant

Plant B is an inclined screen/cone crusher secondary portable plant as shown in Figure 8. The coarse feed to the plant, -10 in., is conveyor belt-fed to a screen feedbox, accelerated over a 20 deg double-deck inclined screen, discharged into a crusher feedbox, crushed in a cone crusher, and finally discharged from the plant onto a transfer belt. The basic equipment in a [illegible] x 14-ft Nordberg inclined double-[illegible] mounted on a structural steel chassis.

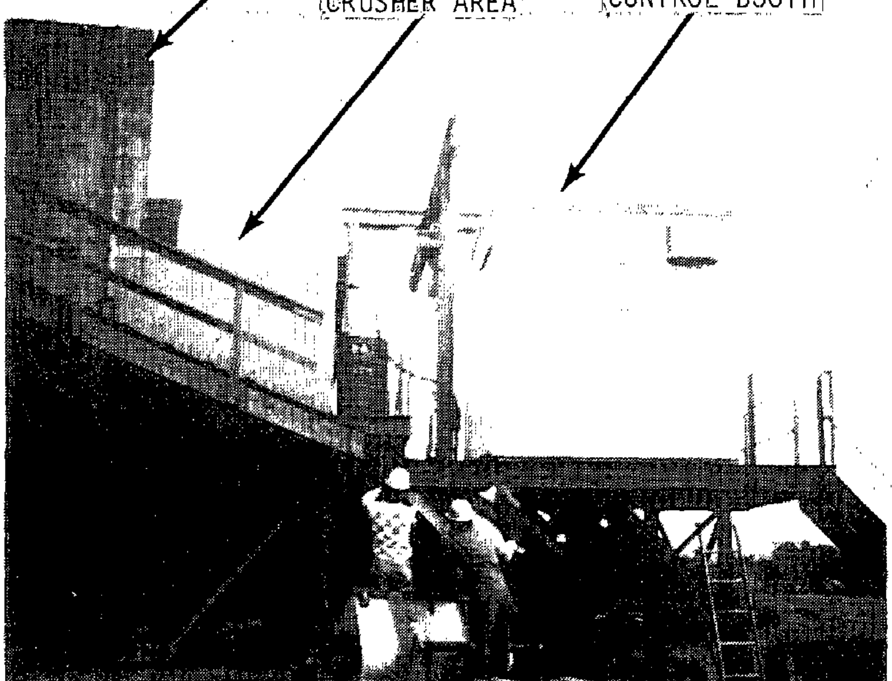


FIGURE 7. - Plant B - control booth at primary station.

Proofer ____________ Typist ____________

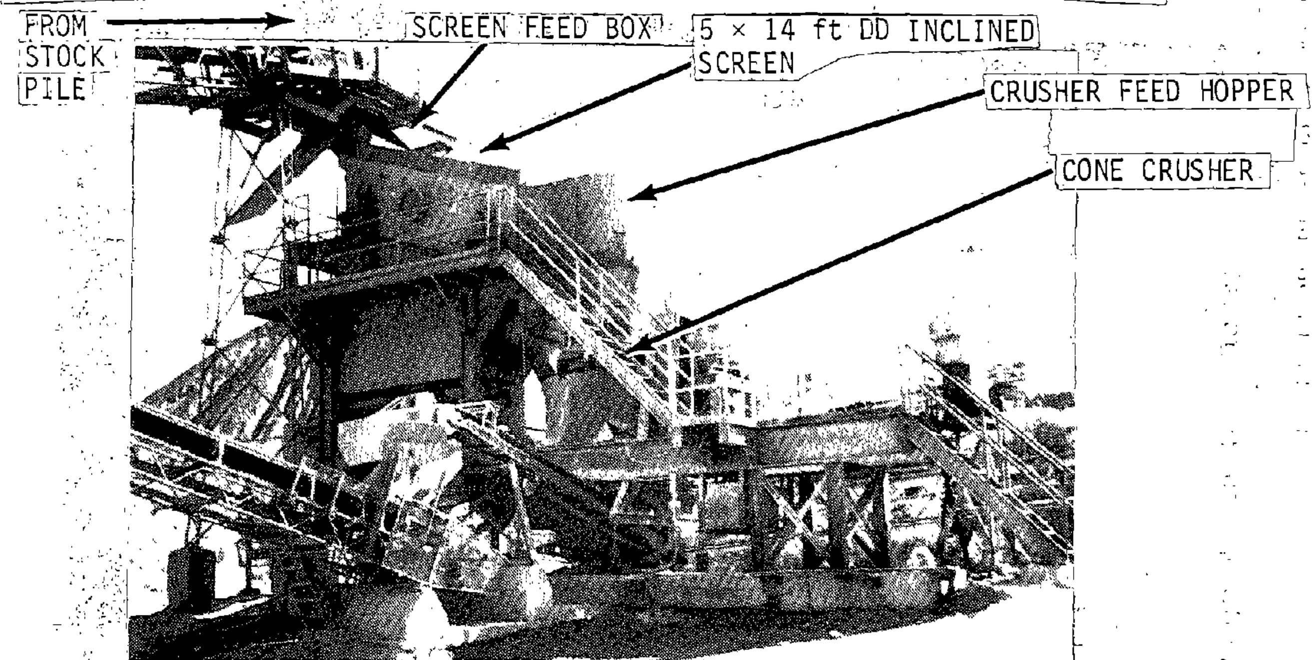


FIGURE 8. - Plant B portable plant.

equipment is a 5100 Standard Symons cone crusher and a 5- × 14-ft Nordberg inclined double-deck screen mounted on a structural steel chassis.

The following subsections discuss the retrofit design for this plant.

3.5.2.1 Feed Chute and Screen Feedbox

A dead bed formed in the chute absorbed the impact of material discharged from the feed conveyor. An internal feed chute shelf retarded the flow of material somewhat, but the feed has considerable inertia as it strikes the screen feedbox or the first screen panel.

An attempt was made to create a dead bed in the screen feedbox to retard the flow, but a sufficient layer of fines could not be built up. A Trelleborg 60A Base Durometer rubber impact pad was then installed (Figure 9). The 3-in. thick pad, mounted on 1/8 in. steel plate, was drilled and bolted to the screen feedbox using 3/4 in. bolts.

FIGURE 9. - Plant B - screen feed end.

3.5.2.2 Inclined Screen

All screen panels were molded 60A Base Durometer rubber mounted on 33 lb frames of structural steel, as shown by Figure 10. Each panel weighed about 110 lb. The first screen panel was a 3-in. thick blank (no holes) and the remaining panels were 3-in. thick with 3-in. diam holes. The rubber panels' hole pattern conformed to the pattern on the AR steel plate they replaced. The panels were mounted to the screen frame using 3/4 in. countersunk bolts. Figure 9 shows the installed screen panels, including the blank panel. Figure 11 presents a sketch of the inclined screen and feed chute.

The first screen panel absorbs the energy of the large feed and decelerates the material as it enters the feed end of the screen. This retarding of material flow keeps the large feed from bouncing down the length of the screen; more evenly distributes the feed across the width of the screen; and, ultimately reduces the impact noise of the material striking the metal structure. The remaining panels of the screen are more than adequate to effectively remove the fines from the +3 in. top size; no production reduction has been experienced.

FIGURE 10. - Plant B - Screen panels and structural steel frames (shown inverted).

Proofer ____________ Typist ____________

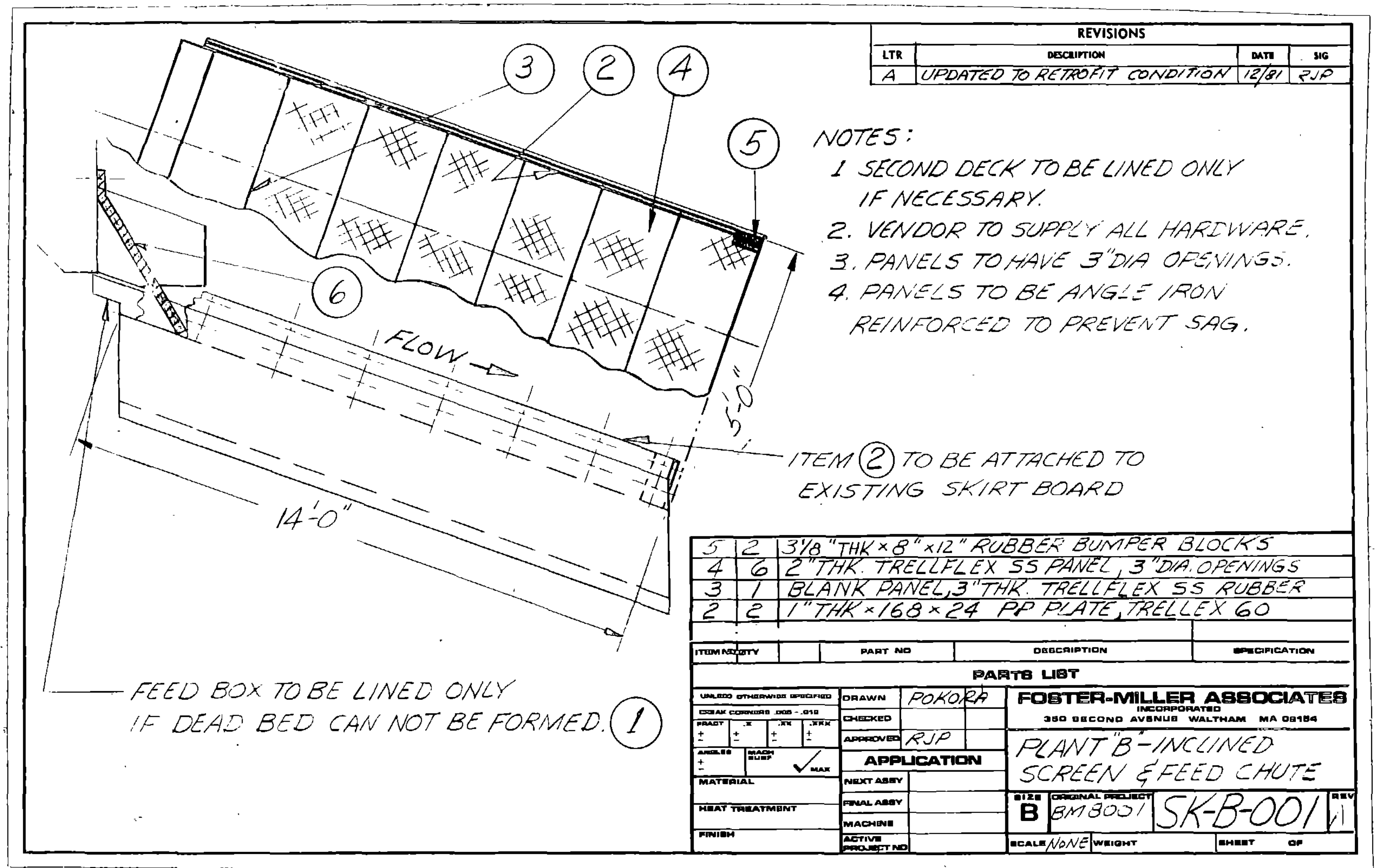


FIGURE 11. - Plant B - inclined screen and feed chute.

Screen side wings, that are used to retain the large feed, are excited by impacting rock, thus radiating noise. These wings have been lined with 1-in. thick steel-backed rubber (Figure 12). The lining is attached to the *wings* of the side plate and not to the side plates themselves, so the structural integrity of the screen has not been affected. The lining was quickly installed by using a Hilti gun which, in essence, shoots a rivet through the lining into the wing. The rivets, however, came loose during operations and the liners were then bolted in place during normal maintenance.

Rubber bumper blocks were added to the side wings right at the discharge lip of the screen (Figure 12). The coarse material traveling across the top deck often became pinched between the vibrating screen corners and the stationary crusher feed chute support. A danger existed that the screen could literally bounce off its support springs during start-up and shut-down if any pinched material restrained the screen's movements. The bumper blocks channeled the screen discharge away from this critical area and directed it more effectively into the crusher feed chute.

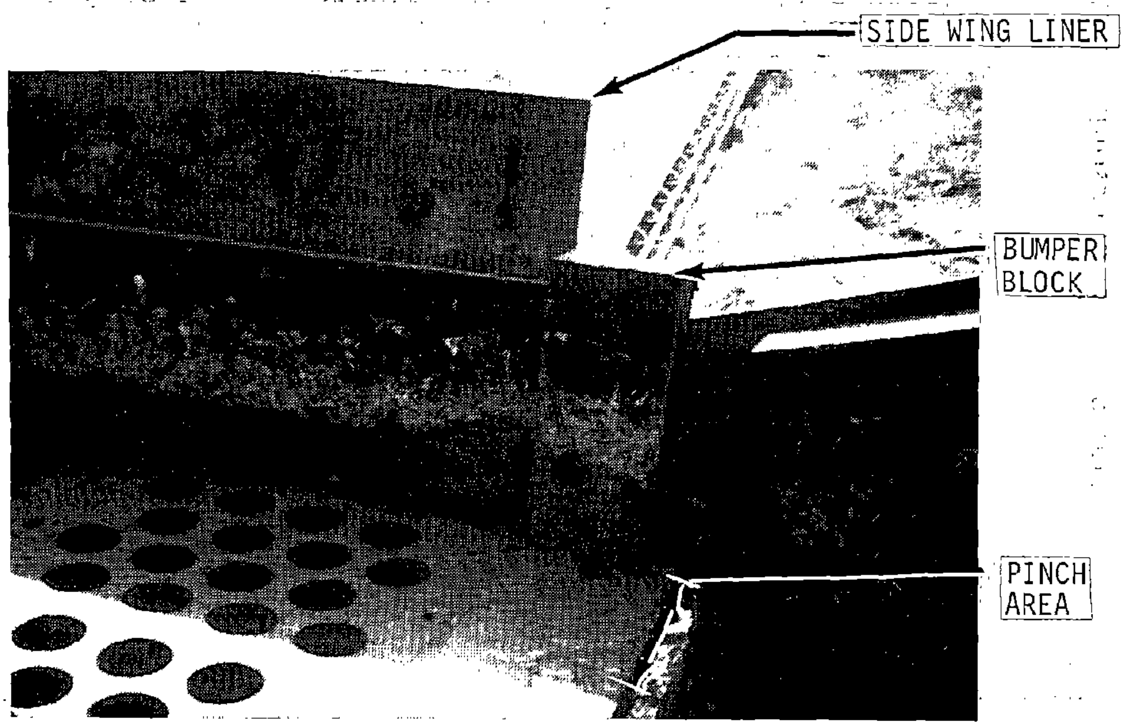


FIGURE 12. - Rubber bumper blocks added to the screen side wings.

The screen top deck discharge lip required a relatively small lining to attenuate the impact noise from the screen overs. Wear is a major problem to be addressed with this modification. The liner must be replaced when necessary to retain the noise reduction achieved from its installation.

A drag curtain (Figure 13) was also installed on the feed chute so the trailing edge of the 2-in. thick curtain hung over the screen feedbox. The curtain was bolted on the outside of the conveyor discharge box with 3/4-in. bolts and a clamp bar. The curtain acted as a retardant for the accelerated feed from the chute and as a means to more uniformly distribute the feed across the width of the screen. *This type of curtain is mandatory as a safety control to prevent coarse feed from bouncing off an inclined screen which has been outfitted with resilient cloth!*

3.5.2.3 Crusher Feed Chute

Figure 14 shows the design of the linings for the crusher feed chute. This design called for lining the entire inside surface of the U-shaped chute with 2-in. thick rubber material.

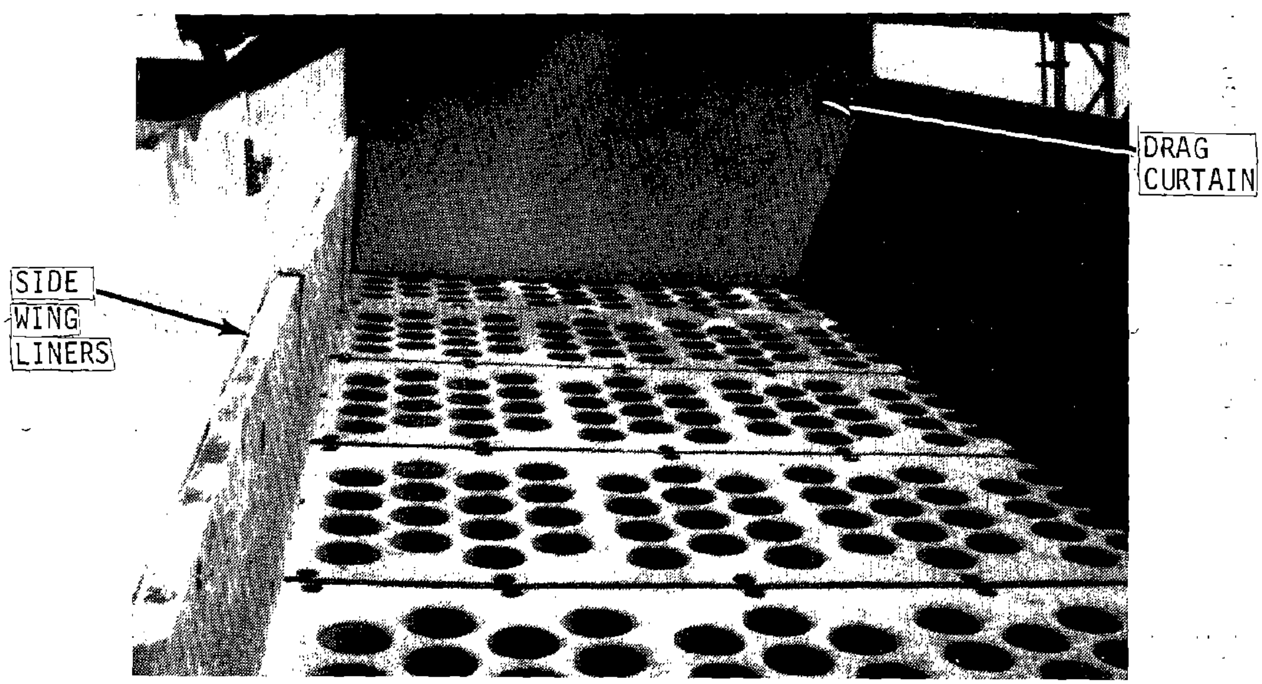


FIGURE 13. - Rubber drag curtain used to retard material flow.

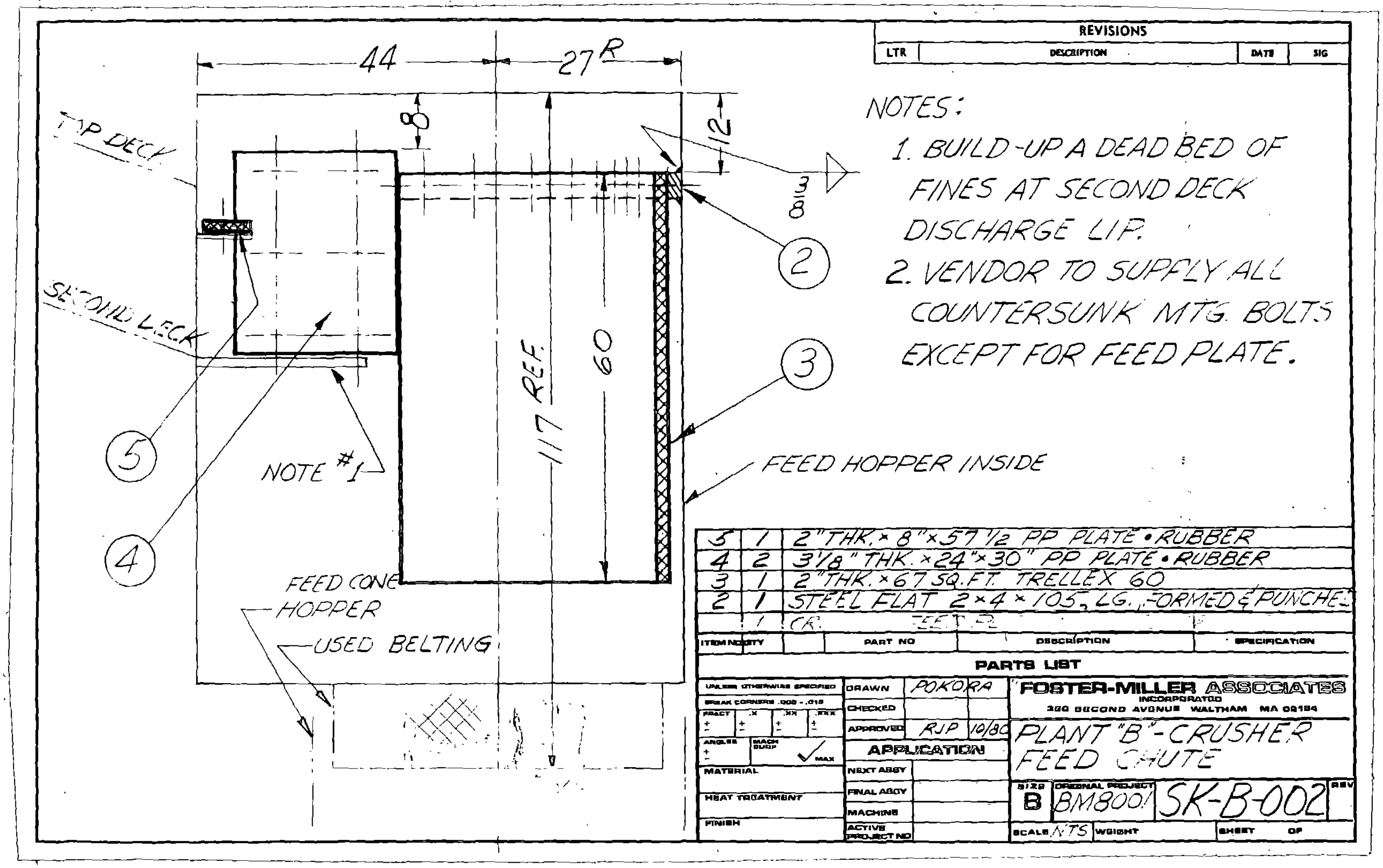


FIGURE 14. - Plant B - crusher feed chute.

The lining was suspended 2 in. from the chute surface to allow the material to flex when impacted. This installation technique allows a reduction of the required rubber thickness-to-impact-load ratio. The rubber liner members were predrilled and fit-up-holes were torch-cut to match the hopper shell. The liner was then bolted into place as shown in Figure 15.

3.5.2.4 Plant B - Crusher

The noise sources in the crusher addressed by the retrofit design were:

a. Crusher feed impacting the gyrating feed plate

b. Feed material bouncing off the feed plate onto the floating feed cone

c. Radiated noise through the crusher main frame shell.

Figure 16 shows the treatment designs used to attenuate noise from these sources.

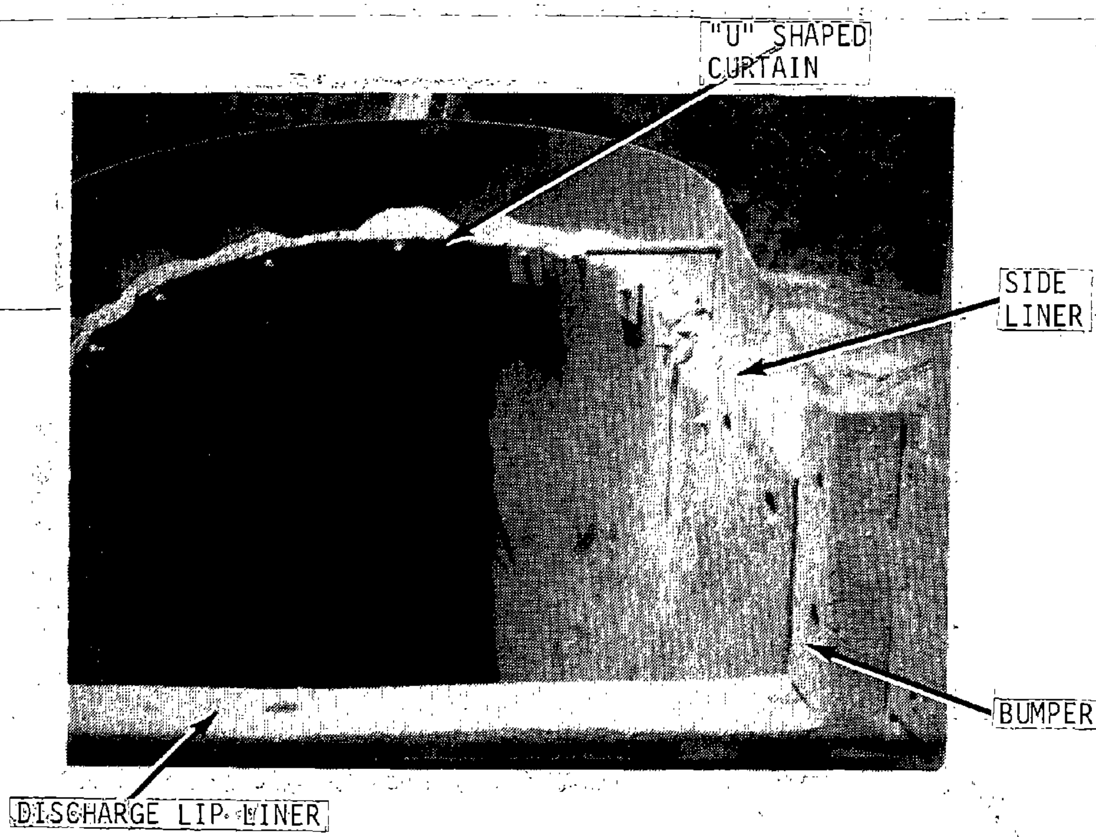


FIGURE 15. - Plant B - crusher feed chute linings.

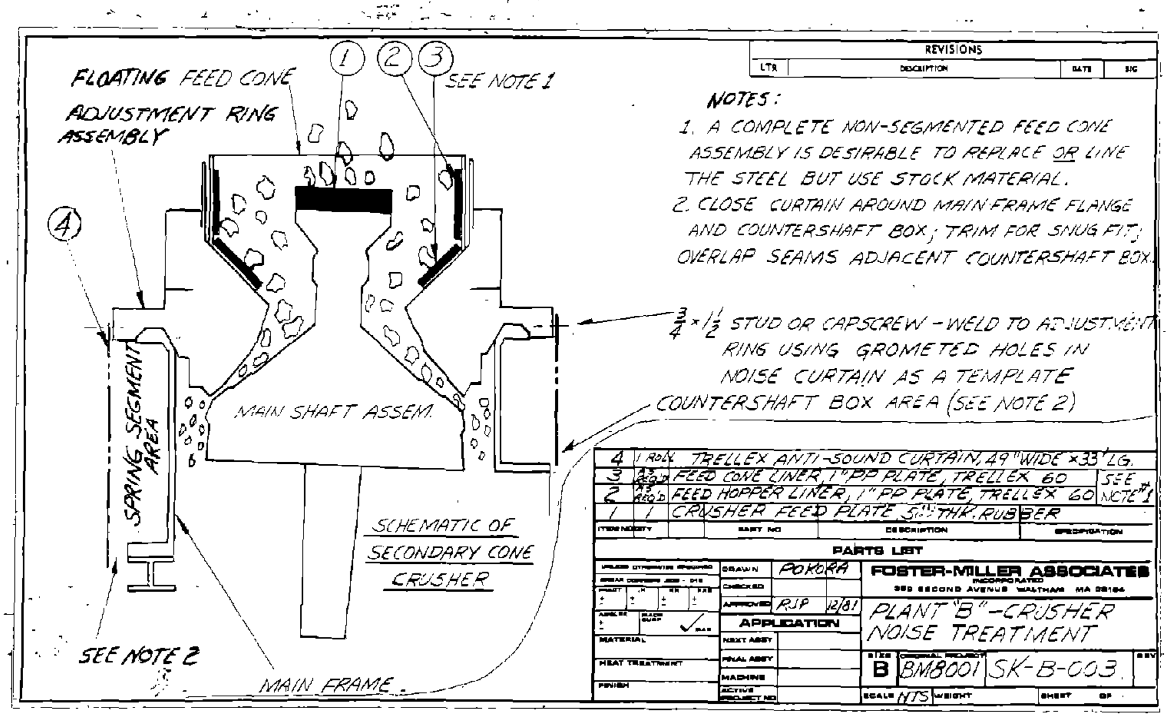


FIGURE 16. - Plant B - crusher modifications.

Feed Plate

A rubber crusher feed plate (Figure 17) replaced the original AR steel plate. The original 5-in. thick rubber mounted on steel plate was incorrectly supplied at 24-in. dia instead of the ordered 27-in. dia. The 24-in. dia plate was installed, but it quickly wore around the mounting bolts and was then replaced with a correctly sized plate. There was no noticeable affect on the crusher's dynamic balance by replacing the steel feed plate with the rubber one.

Feed Cone

The feed cone receives the impact of material being directly discharged from the screen and material bouncing off the feed plate. Liners of 1-in. rubber mounted on steel plate were used to replace the original AR steel plate liners. The rubber liners were supplied in strips. The original steel plate liners were removed. Positions of holes in the liners were marked on the shell and cone. Holes were then torch-cut in the shell and cone and the liners were installed with countersunk roundhead bolts.

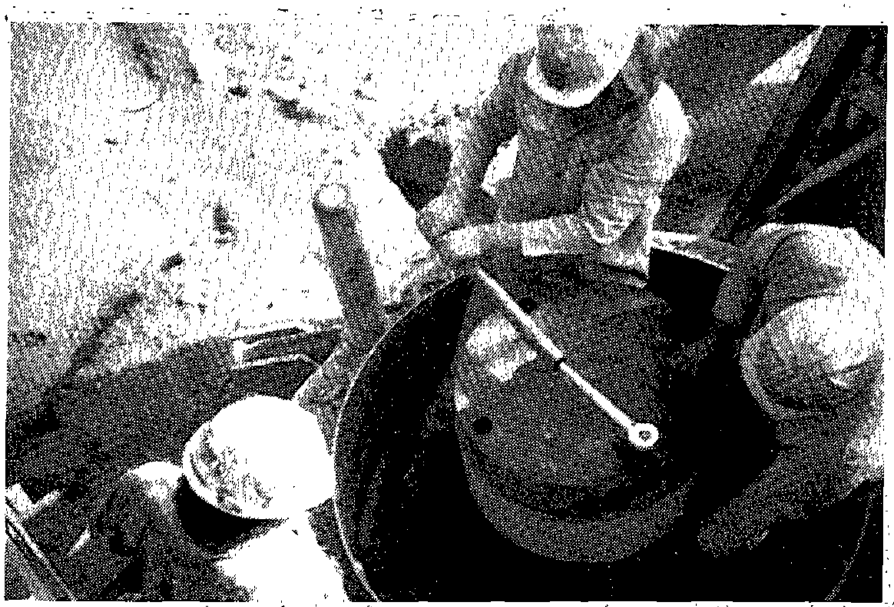


FIGURE 17. - Plant B - installing rubber crusher feed plate.

Crusher Shell

The noise radiating from the crusher main frame shell was caused by the crushing action in the crushing cavity itself. A sound barrier curtain was hung on the outside of the crusher from the adjustment ring to the bottom of the main frame flange (Figure 18). Slits were made in the curtain to allow hydraulic lines to pass through it and the edges of the curtain were overlapped to contain the noise. Since the adjustment ring is an irregular shape, support gromets in the curtain, spaced every 12 in., were used as a template to position and weld 3/4 in. studs on the adjustment ring O.D. The free-hung curtain should not have to be removed during normal crusher servicing and operation; it is free to move with the adjustment ring when the crusher passes tramp iron.

The following Plant B actual costs (excluding the booth) are based on purchase prices for the designs presented using quarry labor for installation:

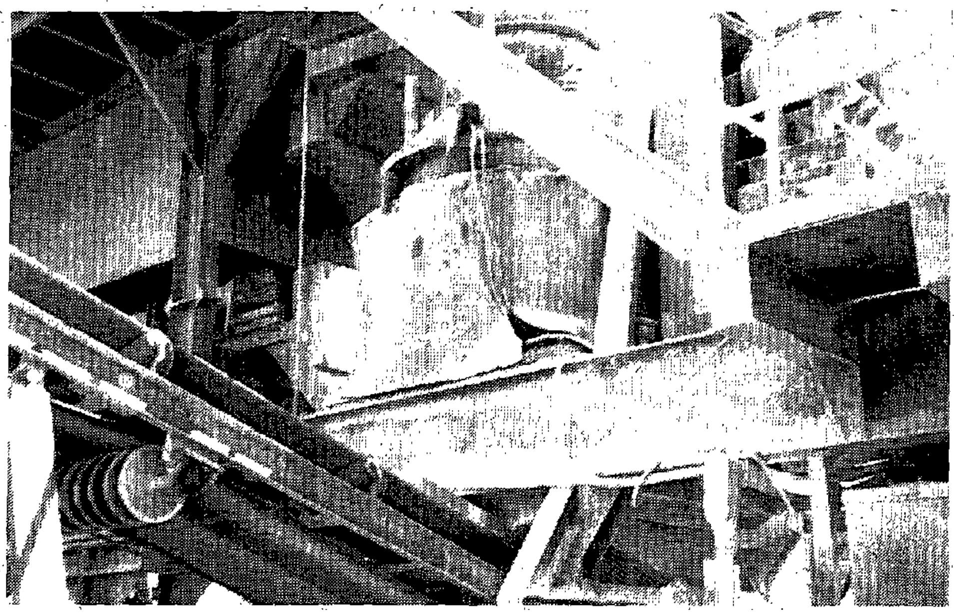


FIGURE 18. - Curtain installed around the crusher main frame shell.

a. Raw material = $14,000

b. Installation time:

1.	Screen feedbox	=	2 manhours
2.	Screen deck, wings, drag curtain	=	16 manhours
3.	Crusher feed chute	=	12 manhours
4.	Crusher feed plate	=	3 manhours
5.	Crusher feed cone	=	30 manhours
6.	Crusher sound curtain	=	3 manhours
	Total	=	66 manhours

A more detailed cost analysis for Plant B is presented in Section 4.

3.5.3 Plant A - Horizontal Screen/Cone Crusher Module

Plant A is a horizontal double-deck screen/cone crusher secondary module as shown in Figure 19. Plant A receives a pre-crushed and stockpiled ROM -10 in. material. The coarse feed is conveyor belt-fed to a screen feedbox, transported over the screen by the screen throw into a cone crusher, and finally crusher-discharged onto a transfer belt to the tertiary stage.

The basic equipment, mounted on a structural steel portable chassis, was a 4-1/4 ft Standard Symons cone crusher receiving the overs from a 5- × 14-ft Cedar Rapids horizontal double-deck screen during the initial survey and design phase of the program.

After design but prior to retrofit, the quarry owner found it difficult to maintain the crusher closed side setting due to worn-out crusher components and faulty hydraulics. The owner decided to replace the crusher with a Model 1500S Telsmith cone crusher installed on the same chassis. Modifications to the

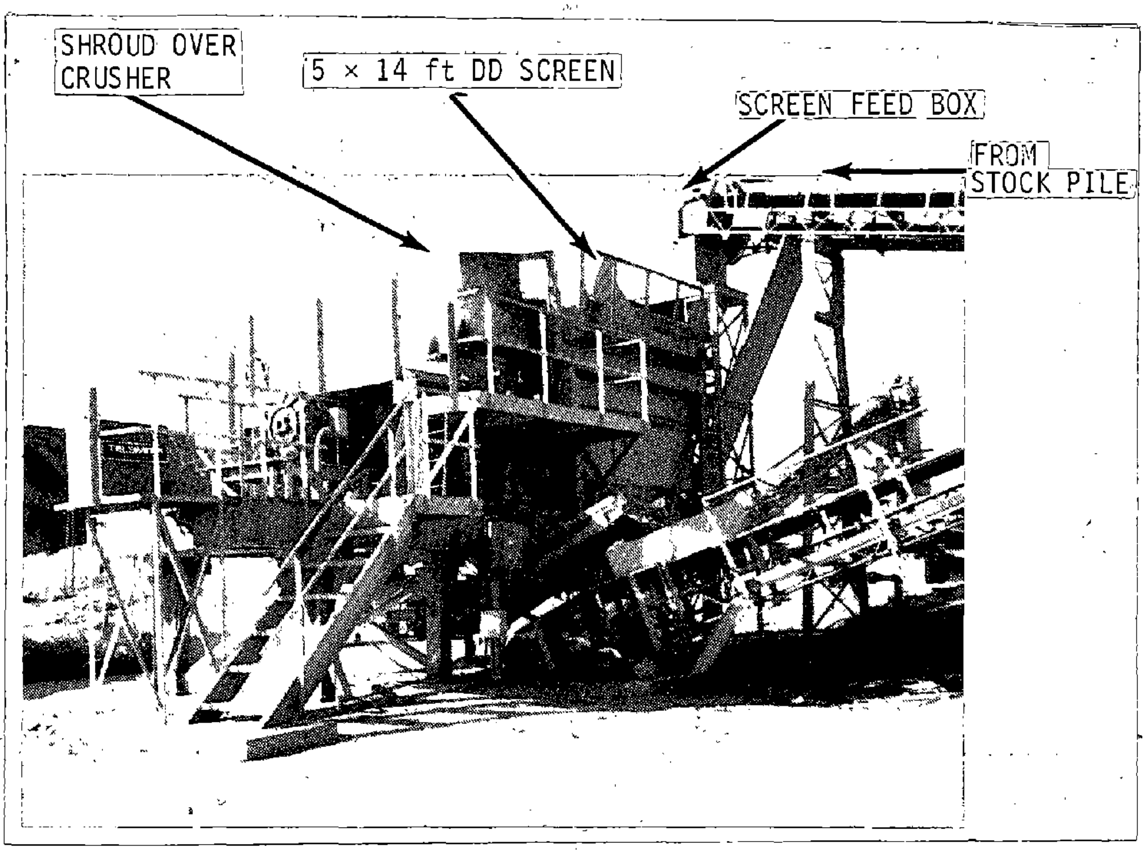


FIGURE 19. - Plant A - portable plant.

chassis were made to accommodate the crusher main frame flange, the screen support, and the feed conveyor position. The new crusher had a greater capacity and is now fed the overs from both the 3-in. opening top deck and the 1-1/2 in. opening second deck of the 5- × 14-ft Cedar Rapids screen, at a capacity of over 325 tph. After the circuit was balanced, the feed to the plant returned to -10 in. material.

General design goals for this plant included:

a. Minimize impact noise at the screen feedchute

b. Attenuate noise on the screen top deck area

c. Attenuate noise at the screen discharge area

d. Reduce impact noise at the crusher feed.

The following subsections discuss the retrofit design for each of the considerations listed above.

3.5.3.1 Plant A - Screen Feedchute

Figure 20 shows the retrofit design for the screen feedchute. A preliminary design for the feedchute included two cable-hung impact panels for the primary conveyor discharge to the feedbox. When the new crusher was installed, however, there was only room for one impact panel in a nearly vertical position - not the preferred 45 deg position. The single panel, manufactured by Durex, was 2-in. thick urethane, 88A Base Durometer, reinforced with 3/8-in. square opening, Grade 10 woven wire cloth. The panel was bolted into the feedbox side frame.

The original retrofit design also did not include a bottom chute liner. During the follow-up visit, fines were observed to build up in the chute creating a dead bed. When the feedchute was reworked as described above, the fines could not be retained in the chute. A Durex 2-in. thick urethane screen panel with 3-in. square openings and reinforced as described above was fitted and bolted onto the bottom of the chute. The holes effectively filled with fines creating a dead bed.

3.5.3.2 Plant A - Horizontal Screen

The screen feedbox was lined with a panel containing uniformly spaced 3-in. openings (approximately 80 percent open area). Panel material was 2-in. thick urethane, 88A Base Durometer wire-cable reinforced. The liner was tightly fitted to the sides of

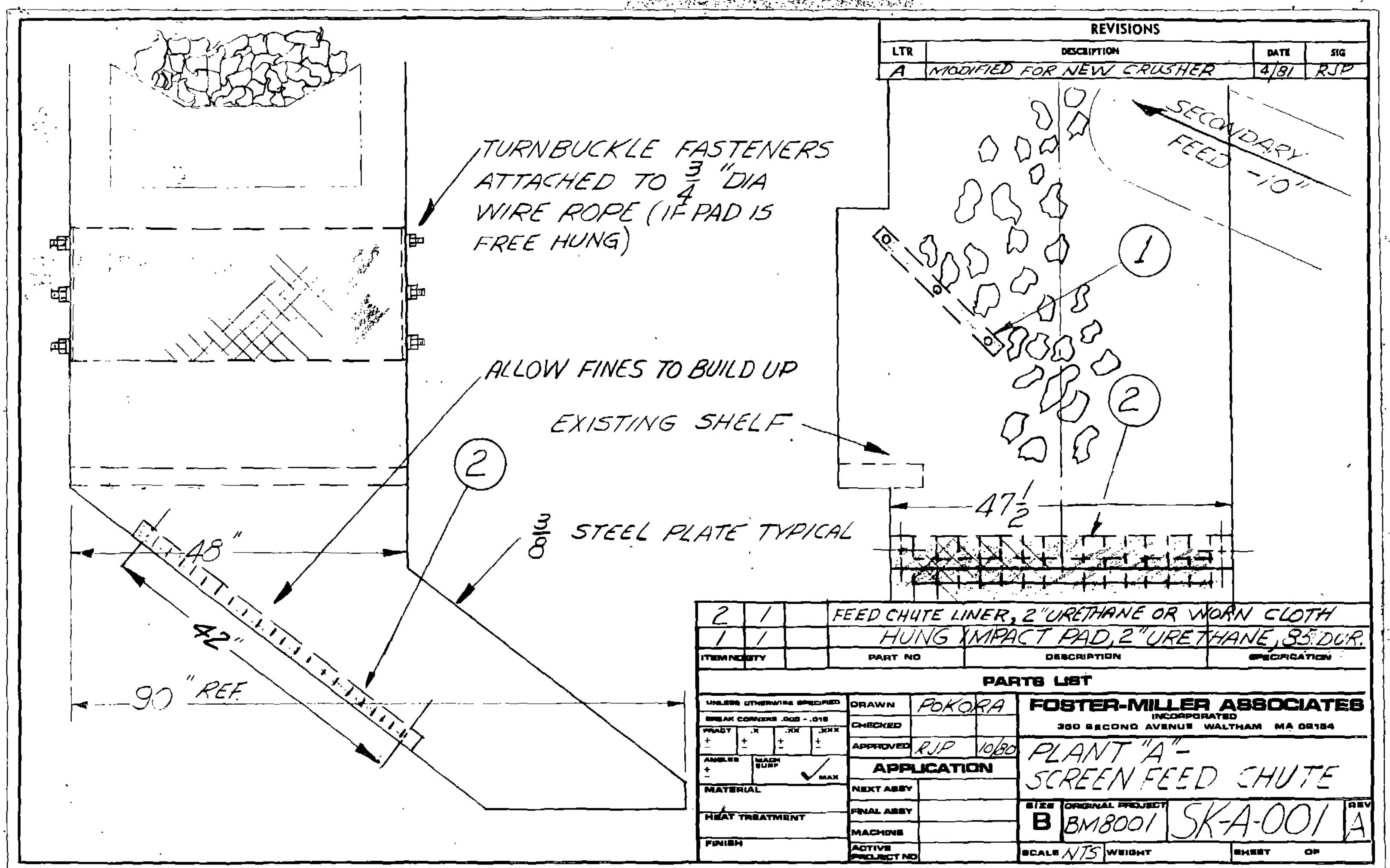


FIGURE 20. - Plant A - screen feedchute.

the feedbox and bolted in through the sides. A bed of fines was captured and eventually built up over the liner pockets, as shown in Figure 21.

The original 5- × 14-ft double-deck screen was outfitted with a top deck of 5/8 in. thick manganese plate with 3-in. dia holes. The bottom deck was 1-1/4 in. square wire cloth. The top deck always discharged into the crusher but often the second deck and minus 1-1/4 in. "throughs" were stockpiled or sent to the tertiary plant.

The screen shown in Figure 22 was initially retrofitted with resilient cloth on the top deck only. After the new crusher was installed, the second deck was also retrofitted with resilient cloth. The top deck was retrofitted with Durex, 2-in. thick urethane, 88A Base Durometer, screen cloth with 3-in. square openings (Figure 23). The urethane was reinforced with 5/8 in. square opening, Grade 10, woven wire cloth. Screen panels were installed with urethane coated side tension rails and hold-down U-bolts as shown in Figure 24. The second deck panels were 1-1/2 in. thick urethane with 1-1/2 in. square openings, reinforced as described above.

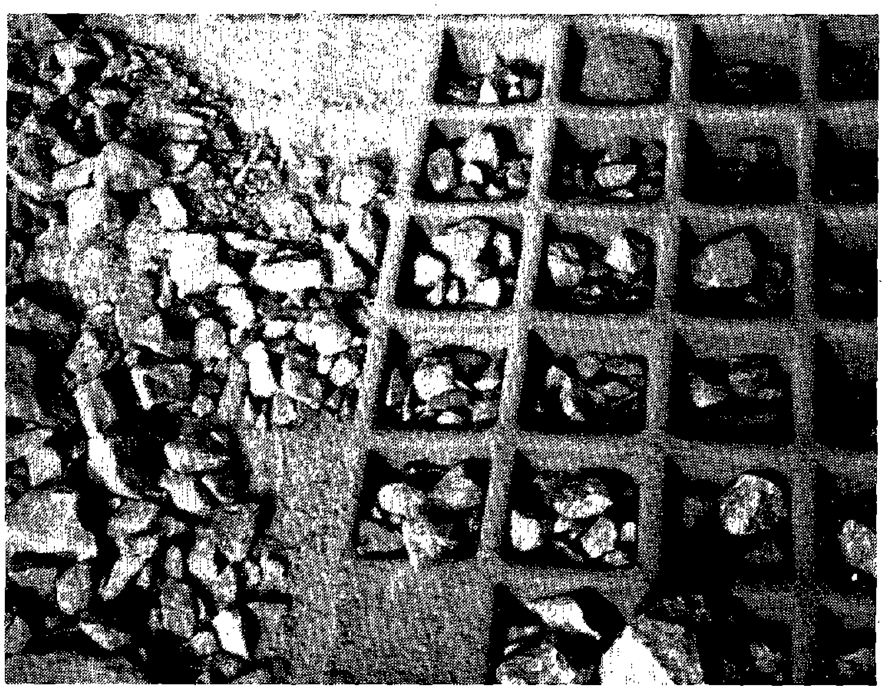


FIGURE 21. - Screen feedbox lining.

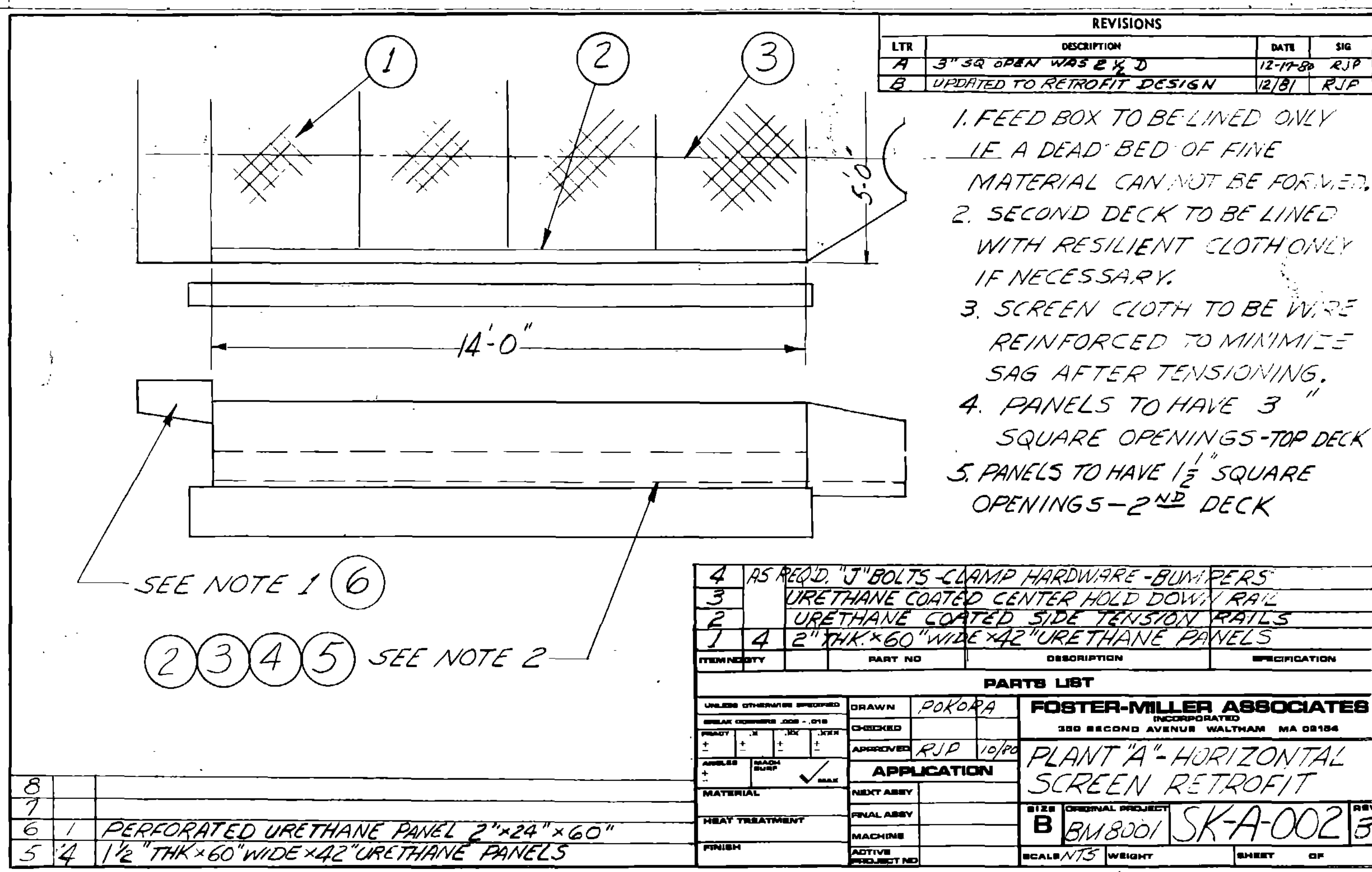


FIGURE 22. - Plant A - horizontal screen retrofit.

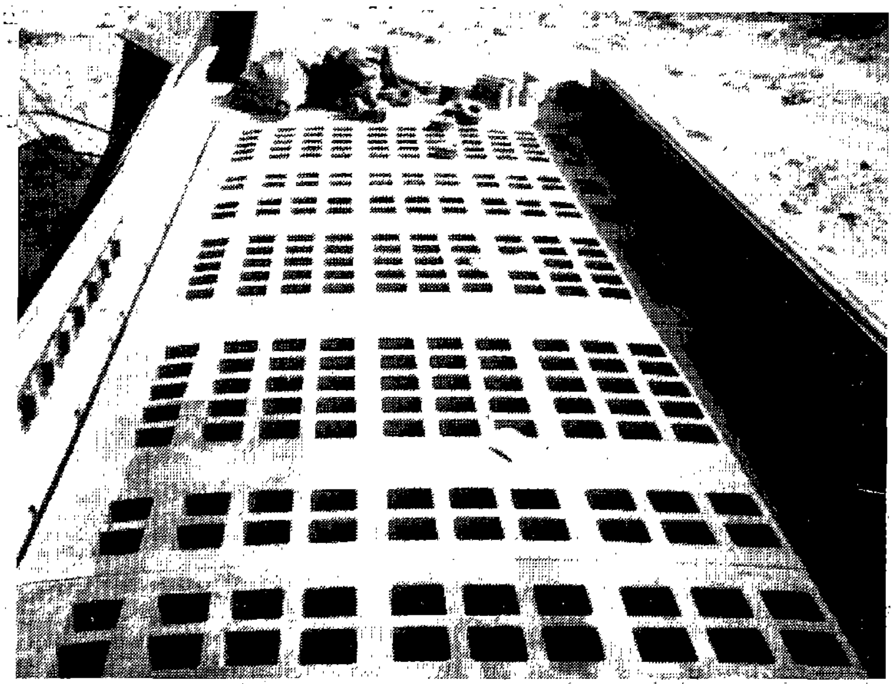


FIGURE 23. - Plant A - screen panels.

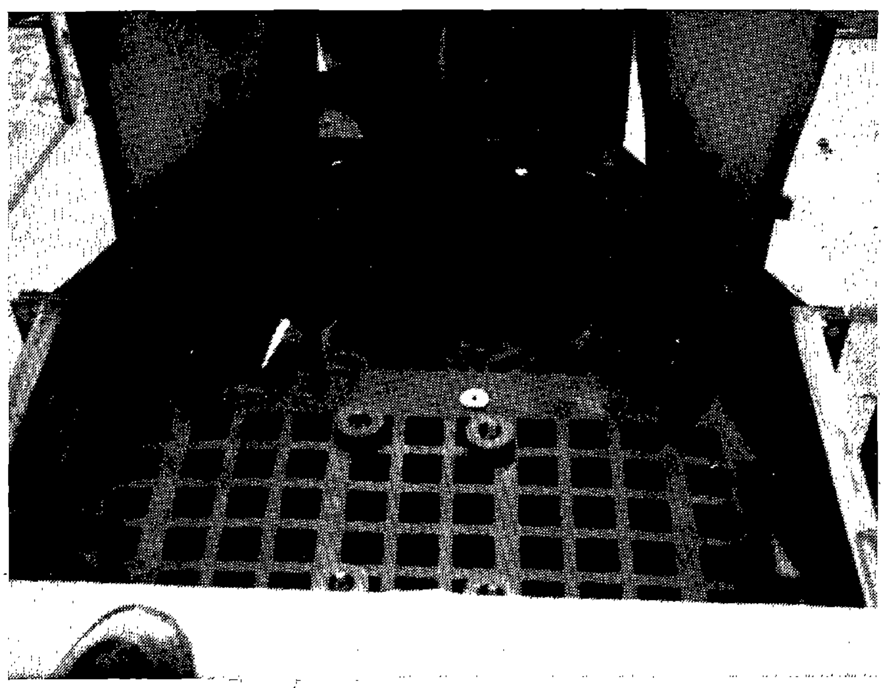


FIGURE 24. - Screen panel with hold-down bolts and donuts.

Proofer ______ Typist ______

The combination of the larger openings and the reduction in percent screen deck open area typical of resilient cloth did not overload the tertiary circuit. Urethane side plates were installed on the top screen deck, but the coarse feed abraded them quickly. Wooden side boards and conveyor belting were used to replace the urethane side plates.

3.5.3.3 Plant A - Screen Discharge to Secondary Crusher

Screen Discharge Lip

The original screen incorporated two discharge lips to convey the overs from each deck to the crusher. The initial retrofit design considered lining only the top lip and its sides which came in contact with the coarse crusher feed. When the new crusher was installed, the top screen discharge lip was removed and the overs from both decks impacted on an enlarged second deck discharge lip. Figure 25 illustrates the modified discharge lip treatment and the screen discharge area. Discharge lip liners were cut in the field to the dimensions of the modified lip. The liners were Durex 1-1/2-in. thick urethane, 88A Base Durometer, reinforced with Grade 10 woven wire cloth. The linings were bolted into place (Figure 26). Countersunk holes in the linings kept the 3/4-in. bolts beneath the wearing surfaces.

Crusher Feed Area

A significant amount of noise was generated by material falling into the crusher and striking the conical feed hopper. Eight molded 1-in. thick urethane segments were supplied by Durex to line the conical hopper (Figure 27). The segments were formed to the shape of the conical hopper and the fit was so tight that securing hardware was not required. The urethane segments were reinforced with woven wire cloth, as described previously.

A molded urethane mantle cap was considered in an attempt to absorb the impact of the material discharging from the screen lip. However, the crusher was choke-fed more often than sparsely-fed and the material itself was thought to be a better noise attenuator. Therefore, no changes were made to the mantle cap.

The following Plant A actual costs are based on purchase prices for the designs presented using labor from the quarry for installation:

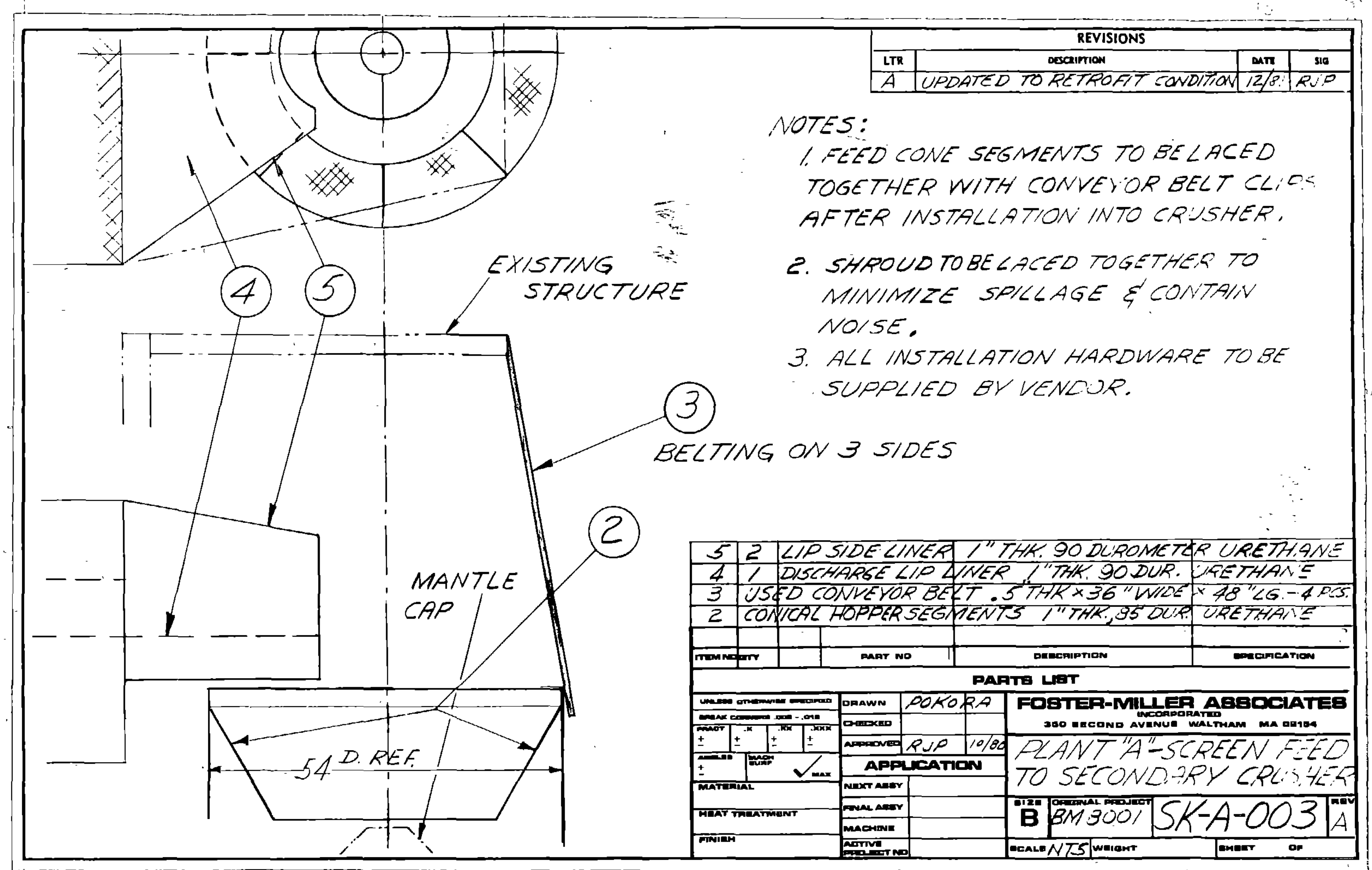


FIGURE 25. - Plant A - screen feed to secondary crusher.

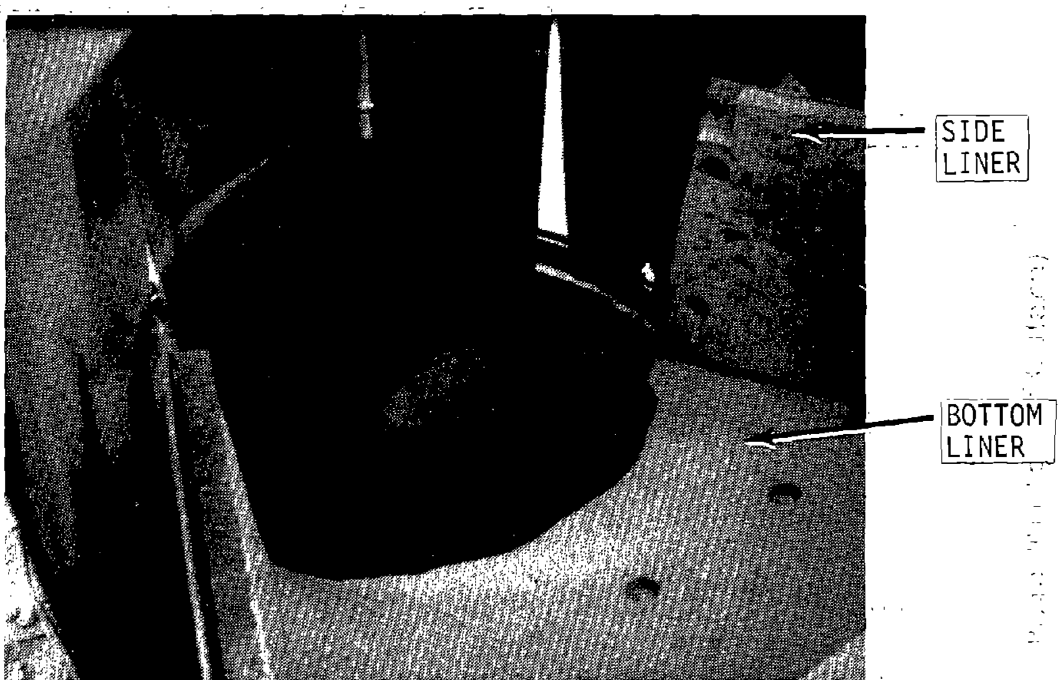


FIGURE 26. - Plant A - screen discharge lip.

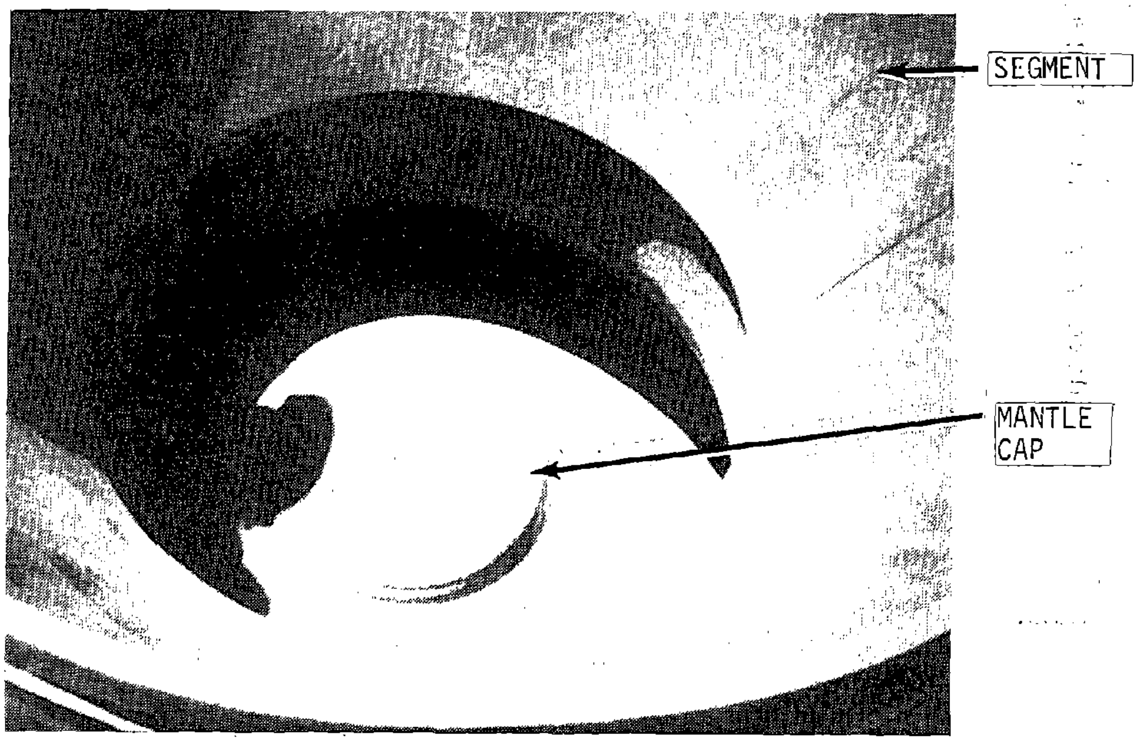


FIGURE 27. - Plant A - conical feed hopper lining segments.

a. Raw material = approximately $17,000

b. Installation time:

1.	Conveyor	=	5.5 manhours
2.	Screen feedbox	=	1.0 manhour
3.	Top deck	=	21.0 manhours
4.	Side deck	=	30.0 manhours
5.	Screen discharge lip	=	1.5 manhours
6.	Crusher cone	=	10.0 manhours
	Total	=	69.0 manhours

A more detailed cost analysis for Plant A is presented in Section 4.4.

3.6 Design and Installation Conclusions

Retrofit noise control treatments at Plant A were Durex urethane, 88A Base Durometer, reinforced with woven wire cloth. Noise control treatments addressed the following sources:

a. Screen feedchute

b. Screen top deck area

c. Screen discharge area

d. Crusher feed.

Treatment costs for the sources totalled $17,000 for capital items and 69 manhours for installation.

Retrofitted noise control treatments at Plant B were Trelleborg 60A Base Durometer rubber. Noise control treatments addressed included:

a. Feedchute and screen feedbox

b. Inclined screen

c. Crusher feed

d. Crusher.

Treatment costs for the Plant B sources totalled $14,000 for capital items and 66 manhours for installation.

The primary crusher noise sources at Plant B could not be reduced in a cost-effective manner. Therefore, a control booth for the operator was designed and installed. Capital items totalled $4919 delivered and installation required 40 manhours.

All of the Plant A and Plant B noise control treatments were installed on a retrofit basis to *accessible* noise sources. The treatments responded to the contract guidelines by meeting the following criteria:

a. The treatments were acoustically effective

b. Only commercially available materials were used

c. No special services or facilities were required to fabricate, install and maintain the treatment

d. The treatments were durable and cost-effective when properly specified and installed

e. The modifications had a minimal impact on the plant/module operation.

Acoustical effectiveness and durability is addressed in Section 4 for the installed noise control treatments.

4. FIELD DEMONSTRATION RESULTS

FMA personnel were on site during the installation of the treatment materials and participated in startup and fine-tuning activities. The noise surveys were repeated at this time at both plants to determine the effectiveness of the modifications. Monthly followup visits were conducted at each plant during the first 6 months of the program. Field modifications were made during some of the followup visits. The noise surveys were repeated during the visits to determine noise control effectiveness and to note wear on the resilient materials.

The following subsections present the field demonstration results and an analysis of the cost-effectiveness of the retrofit program. Noise survey data are first presented comparing measured noise levels taken before and after installation of the modifications. Successive followup noise survey data are presented in a manner that allows determination of the performance (or lack of performance) of the treatment materials as wear occurred.

4.1 Portable Plant A - Noise Control Treatment Effectiveness

The retrofit program at Plant A was initiated on 27 April 1981. Prior to any material installation, new baseline noise levels were monitored at specified locations as described and shown in Figure 28. These measurement locations include 4 stations which represent typical cleanup areas (1 to 4 in Figure 28) and three stations next to the major noise sources (5 to 7 in Figure 28). During the followup visits to Plant A, all measurements were made at the specified locations.

Table 24 presents a chronology of the retrofit installation and modifications and the schedule of followup visits between the period 27 April to 20 October 1981. Circuit conditions are briefly described as well as a summary of the observed deterioration of the installed treatments.

4.1.1 Initial Treatment

During the initial treatment on 28 April 1981, the following materials were installed:

a. Resilient top screen deck

b. Resilient impact pad in the screen feed chute

c. Conical liner in the crusher feed hopper.

Measurement Location	Sound Pressure Levels										
	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
1. Ground level 3 ft from belt 6 ft from plant	98	86	88	93	94	95	93	91	88	83	76
2. Ground level clean-up areas	98	84	86	91	94	93	93	91	89	83	76
3. Ground level	90	90	86	91	93	92	91	88	85	79	75
4. Ground level	98	88	86	93	92	95	95	88	81	74	72
5. At crusher 2 ft from crusher 4 ft from rail	105	94	94	98	100	102	101	97	93	86	78
6. At screen 2 ft from discharge lip	113	92	92	100	100	104	107	109	106	98	88
7. Screen level feed end of screen	106	95	92	93	97	99	102	101	96	88	80

Sketches, comments and notes

All measurements taken at approximately waist level.

These measurements are before retrofit.

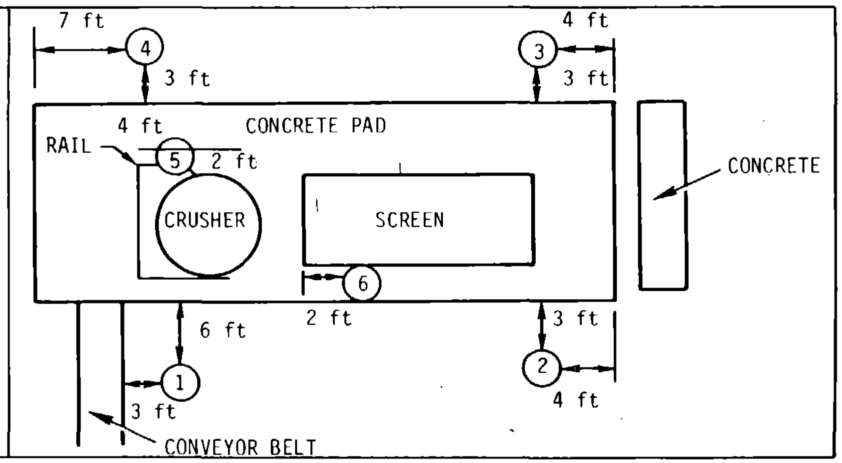


FIGURE 28. - Plant A - noise data base.

Figure . Vertical Full Page Title (Sit Here)

Proofer ______ Typist ______

TABLE 24. - Plant A - retrofit chronology

Date	Retrofit number	Circuit condition	Noise treatment	Wear description
4/27/81	Before retrofit	New Telsmith 1500S cone crusher in operation 1-1/2 weeks. Feed approximately -14 in., screen decks and chutes heavily loaded. Circuit fine-tuning in process.	None to date.	-
4/30/81	1	Same as 4/27/81. Feed to screen striking underside of vibrator due to increased thickness of resilient cloth.	1. Top screen deck and rails. 2. Chute impact pad. 3. Conical hopper liner.	Resilient material new.
6/9/81	2	Feed reduced to -10 in. Screen heavily loaded. Circuit tuning still in progress to obtain optimum capacity. Crusher feed not striking conical hopper liner consistently.	1. Screen discharge lip liners. 2. Screen feedbox liner. All treatment elements installed per design except second screen deck.	Feed chute liners badly worn. Top deck wearing rapidly including hold-down bolts and side tension rails, top deck side liners removed (worn out).
6/23/81	3	Circuit optimized and processing 100% passing 10 in. feed. Screen bed depth good but conveyor belting installed on underside of screen vibrator to minimize impact on housing. Screen vibrator very loud and housing running hot thereby making shrouding impractical on a retrofit basis.	Second screen deck retrofitted with urethane cloth.	All installed treatments except top deck are almost completely worn out at 120,000 tons. Feed chute impact pad worn through and ineffective.
7/20/81	3 - Modification No. 1	Same as 6/23/81.	Top screen deck urethane panels at discharge end replaced with AR steel plate. Remaining panels rotated to get more life. Worn feed chute liners replaced with AR plate.	-
8/26/81	3 - Modification No. 2	Same as 7/20/81.	Top screen deck changed back to full AR steel plate.	No chute liners. Conical hopper liner worn but still in place. Second screen deck wearing rapidly.
10/20/81	Final visit	Same as 8/26/81.	Same as 8/26/81 except second screen deck almost worn out.	

Proofer ____________ Typist ____________

As described in Section 3, modifications had been made to the plant by the quarry owner between the design and installation of the retrofit materials. As a result, the screen discharge lip liner and screen feedbox liner supplied by Durex required remanufacturing. Liners could not be field-modified to meet existing conditions.

Noise measurements performed on 30 April 1981 showed a 4 dBA reduction at measurement location 6, located beside the screen 2 ft from the discharge lip. A 5 dBA reduction was observed at measurement location 7 located beside the screen feedbox. Little or no improvement was observed at other measurement locations.

Figures 29 and 30 show the octave band levels monitored at locations 6 and 7 on 27 and 30 April 1981, as well as during subsequent modifications. Refer to Appendix C for octave band levels monitored at the remaining locations during followup visits after modifications. As can be seen in Figures 29 and 30, significant reductions occurred primarily in the 500 to 4000 Hz octave bands.

4.1.2 Modification 2

On 9 June 1981, the screen discharge lip liner and the screen feedbox liner were installed. During the period from 30 April to 9 June, materials installed during the initial treatment were wearing significantly. On 9 June, the top screen deck was troughing and showing significant wear around the openings. Hold-down bolts and side tension rails were also failing. The resilient liner installed in the screen feed chute was also badly worn. The screen top deck side liners had worn out and were removed.

Noise measurements made on 9 June, after the installation of the screen discharge lip and resilient screen feedbox liner, showed an improvement over the 30 April measurements of 2 dBA at measurement location 5, 2 dBA at location 6, and no improvement at location 7. Octave band levels measured at location 5 are shown in Figure 31. No improvement was measured at any of the four monitoring locations at ground level.

Analysis of the data from modification 2, together with on-site observation, led to the conclusion that because of circuit conditions at Plant A, the bottom screen deck was also a significant noise source that could be addressed by retrofit. Resilient screen cloth was ordered.

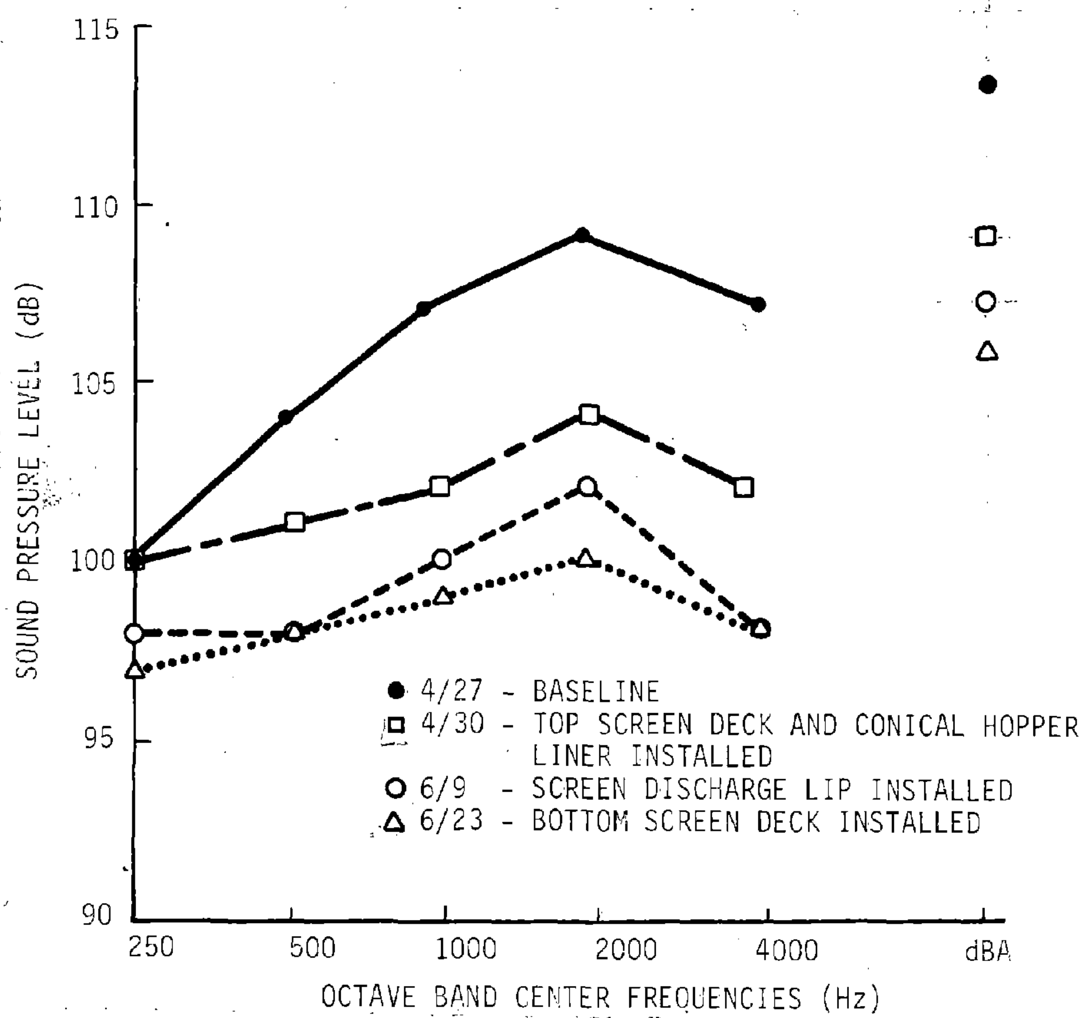


FIGURE 29. - Effects of retrofit treatments at Plant A - position 6 - beside screen discharge.

Proofer ____________ Typist ____________

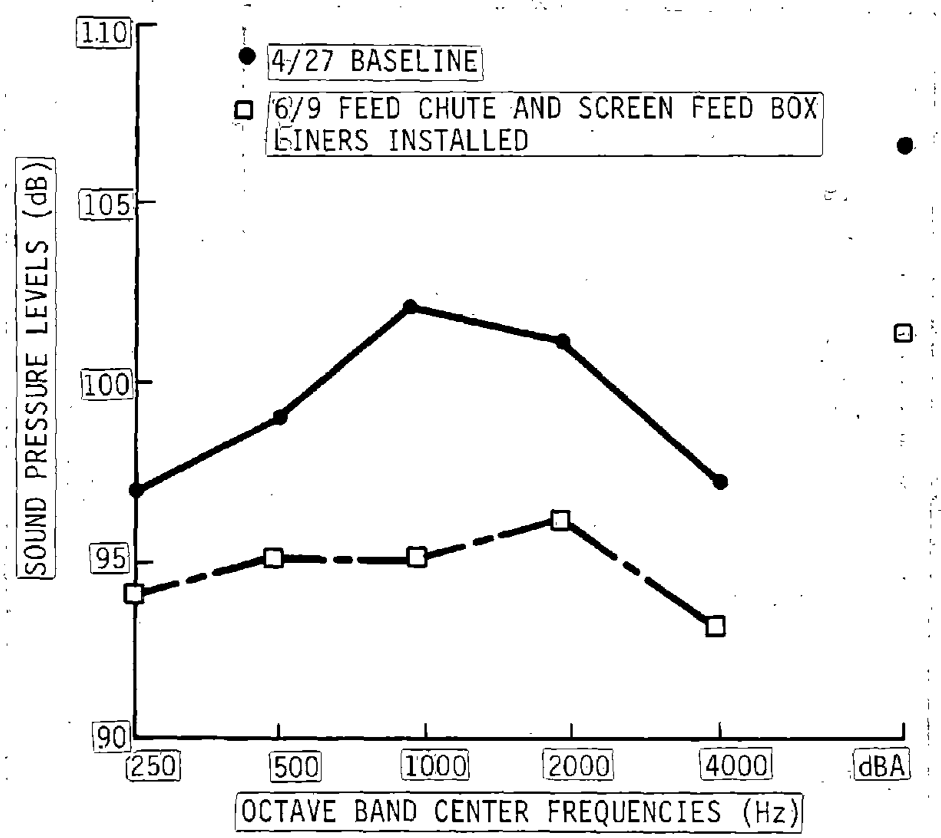


FIGURE 30. - Effects of retrofit treatments at Plant A - position 7 - beside screen feed end.

Proofer

Typist

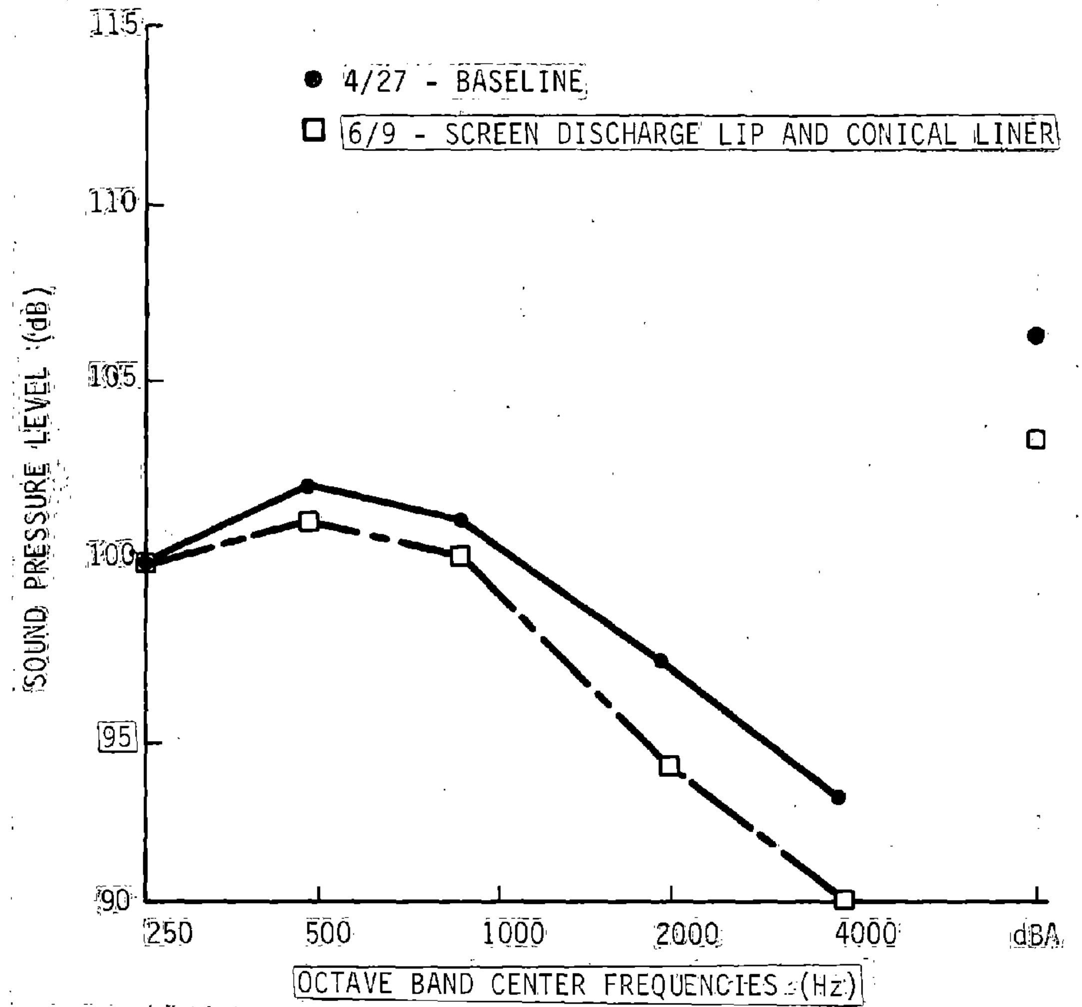


FIGURE 31. - Effects of retrofit treatments at Plant A - position 5 - beside crusher feed.

Proofer

Typist

Consideration was given to enclosing the screen vibrator unit since this was also a major noise source. FMA is aware of successful attempts to attenuate noise of the vibrator unit by some screen OEMs, but this success has been on new screens in a controlled test program in a pilot plant environment. The scope of this program and the specified design criteria did not allow FMA to design and install a special enclosure that reduced the vibrator noise and did not affect the mechanical performance of the screen. An enclosure around the vibrator unit would have retarded the radiant cooling of the housing and bearing life, type of lubricant, lubricant flow, and other screen operating parameters would have been affected. An acoustical enclosure would more than likely have to include a cooling water jacket at this installation, and FMA decided that this was not a cost-effective, simple, off-the-shelf technique to reduce noise.

4.1.3 Modification 3

On 23 June 1981, the resilient bottom screen deck was installed. By 23 June, after processing only 50,000 tons, the screen feed chute impact pad was totally ineffective. The top screen deck was also evidencing additional wear. The only improvement noted after the bottom deck installation was a 1 dBA reduction at both measurement locations 5 and 6.

Analysis of the data and observations by program personnel concluded that further improvements at Plant A would be difficult at best. Premature failure of materials precluded any subsequent retrofits. Followup visits, however, were made to continue to monitor material performance.

4.1.4 Followup Visits

Followup visits to Plant A were made on 7 July, 26 August, and 20 October 1981. By 7 July, the two discharge end panels of the top screen deck had been replaced with AR steel plate. The resilient top deck (Figure 32) had processed 191,000 tons. By comparison, an AR steel plate typically processes 680,000 tons at Plant A. The urethane side rails were replaced after 28,500 tons with used conveyor belting on wooden frames as shown in Figure 33. The feed chute liners were also replaced with steel after processing less than 50,000 tons.

Noise measurements made on 7 July showed that noise levels at all seven measurement locations had returned to baseline levels.

FIGURE 32. Plant A - top deck screen panel.

Proofer ______________ Typist ______________

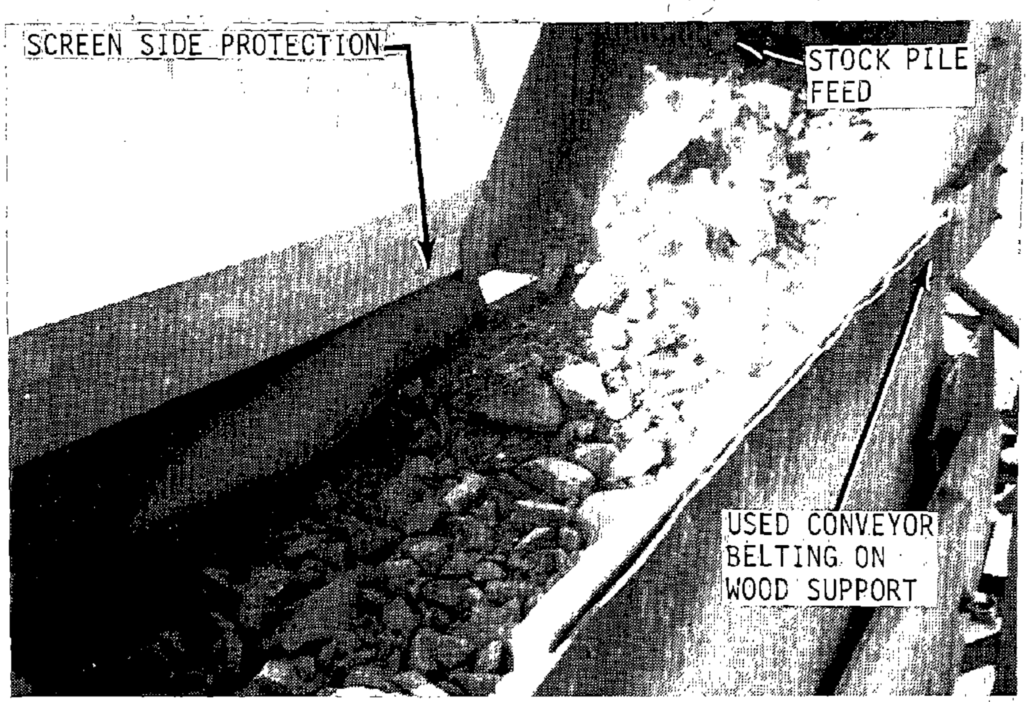


FIGURE 33. - Plant A - screen side protection.

By 26 August 1981, the top screen deck had been completely replaced with steel. Screen feed chute liners (Figure 34) had also been replaced. The screen feedbox liner (Figure 35) was showing wear after processing 165,000 tons, but appeared to still have approximately 50 percent of its original life remaining.

The final followup visit to Plant A was made on 20 October 1981. All resilient materials had been replaced except the conical crusher feed hopper liner and the bottom screen deck. Both, however, were showing significant wear. The screen discharge liners (Figure 36) were replaced after 160,000 tons. The bottom liner (not visible) wore significantly faster than the side liners. Figure 37 shows the conical crusher feed hopper liner after processing 380,000 tons. As can be seen, the upper two-thirds of the liners show little wear. The bottom one-third, however, has worn down to the steel reinforcing wire.

The bottom screen deck cloth, shown in Figure 38, needed replacing at 212,000 tons. The life of the bottom deck was approximately the same as the life of wire cloth.

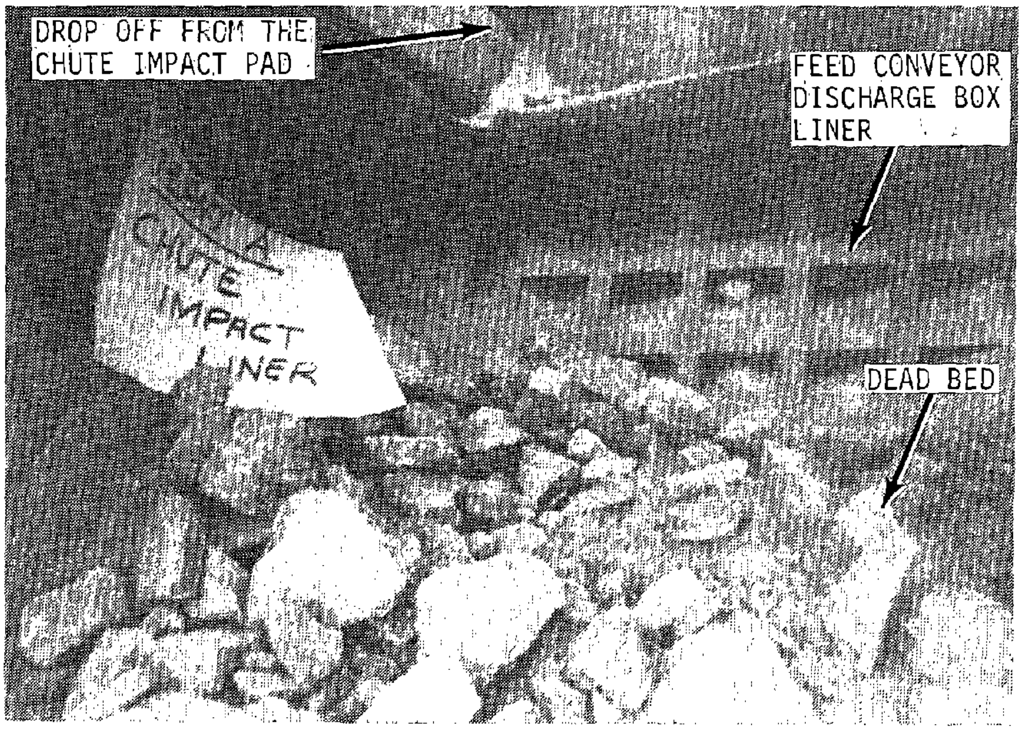


FIGURE 34 - Plant A feed conveyor discharge box liner.

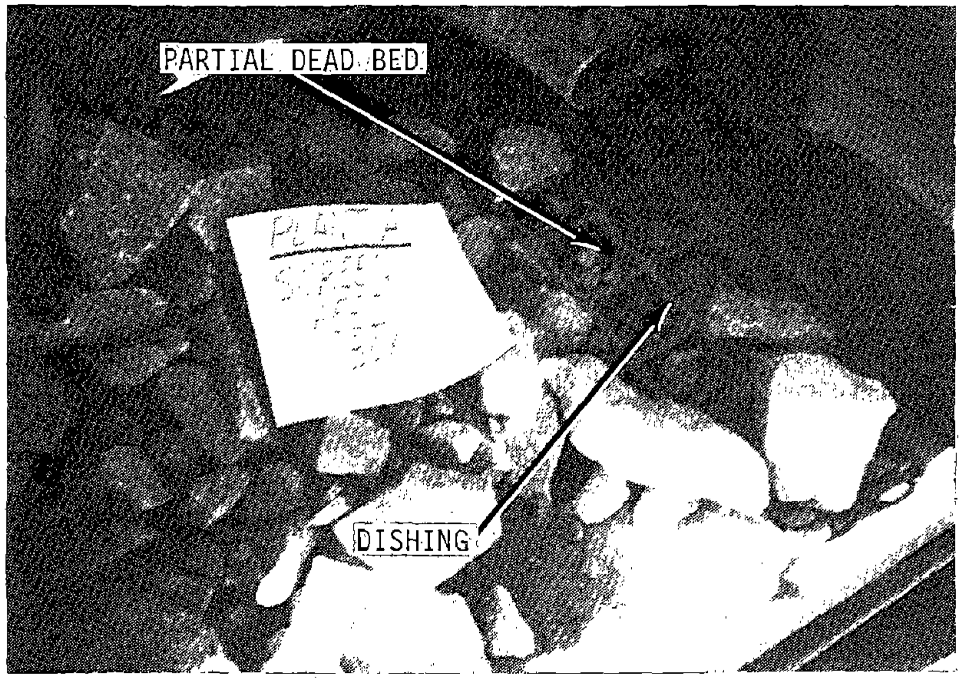


FIGURE 35. - Plant A - screen feedbox liner.

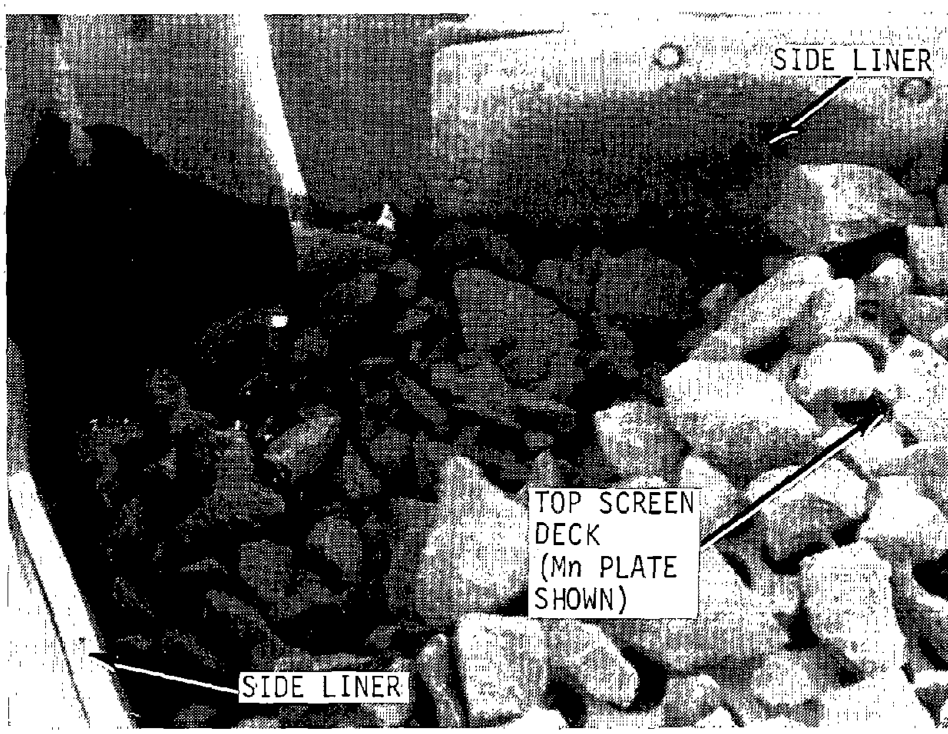


FIGURE 36. - Plant A - screen discharge lip.

Proofer

Typist

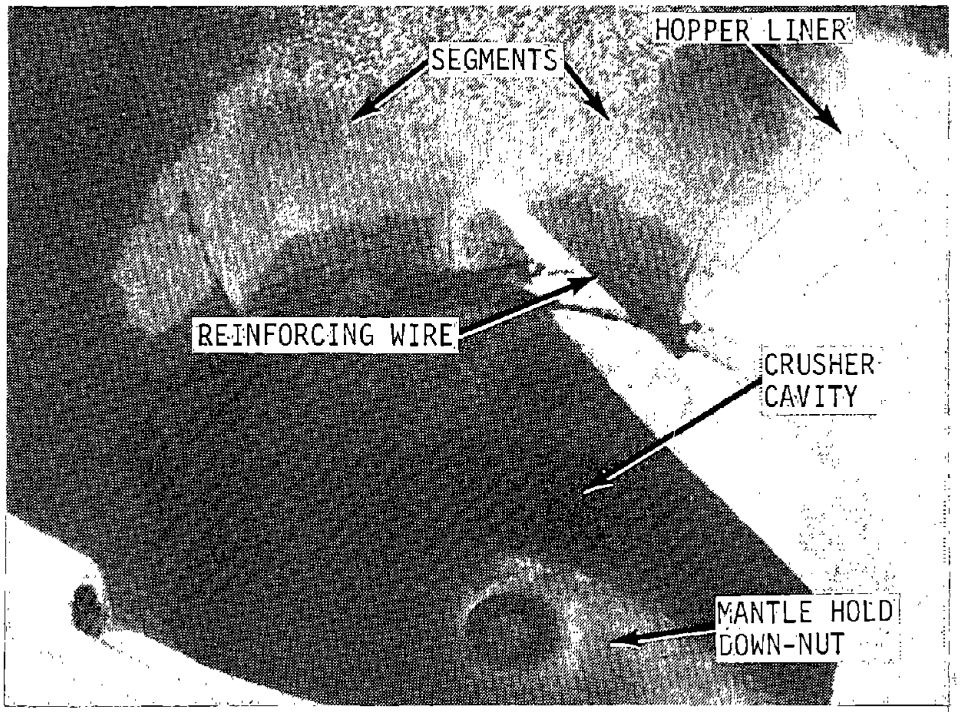


FIGURE 37. - Plant A - conical hopper liner.

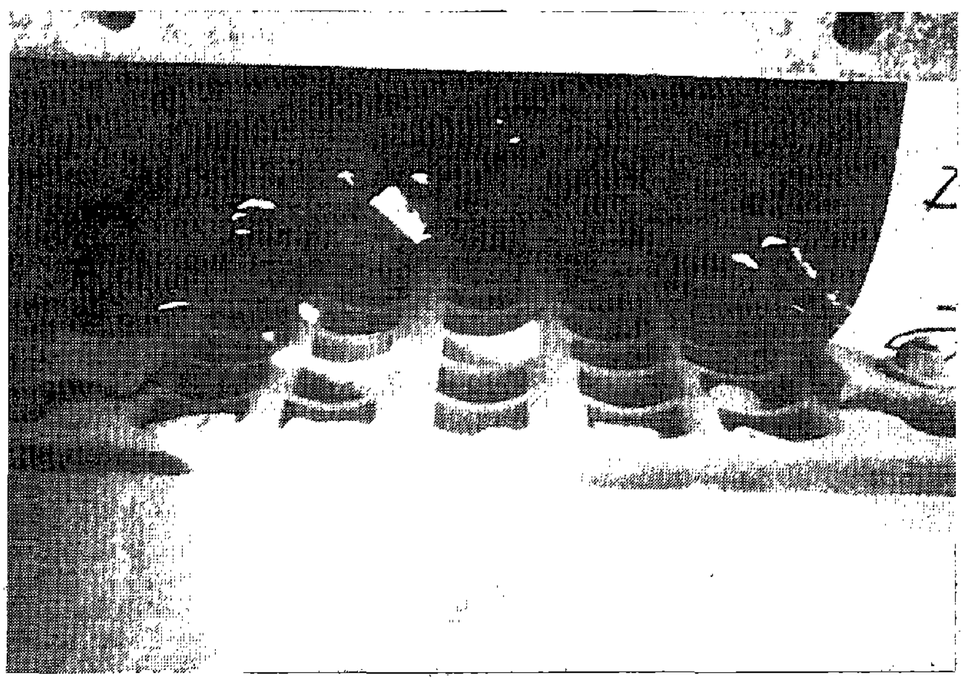


FIGURE 38. - Plant A - second screen deck cloth after 212,000 tons.

4.1.5 Plant A - Summary

During the period 27 April to 23 June, the following retrofit noise control treatments were installed:

- Resilient top screen deck
- Resilient impact pad in the screen feed chute
- Resilient conical liner in the crusher feed hopper
- Resilient screen feedbox liner
- Resilient screen discharge lip liners
- Resilient bottom screen deck.

All installed materials were steel reinforced urethane fabricated by Durex Products, Inc.

Maximum noise reductions of 5 to 6 dBA were measured beside the screen feed and discharge. Little, if any, reduction was measured at ground level cleanup areas. Premature material wear coupled with plant changes between the design and installation phases of the program prevented a progressive retrofit treatment at this plant. As a result, the full potential of the installed treatments could not be assessed.

The premature failure of their materials in this program has caused Durex Products, Inc. to reevaluate the use of urethanes in coarse material handling circuits. They have concluded that the best performance from urethanes is obtained when used in circuits processing minus 1-1/2 in. material and their use with +1-1/2 in. material should not be recommended. Durex now recommends screen cloth made of rubber laminated to steel plate. New cloth has been furnished to Plant A for replacement of the top deck; however, no performance data was available for inclusion in this report.

4.2 Portable Plant B - Noise Control Treatment Effectiveness

The retrofit treatment installation at Portable Plant B was initiated on 24 March 1981. Prior to the installation, new baseline noise levels were monitored at specified locations as reported and shown in Figure 39. The measurement locations included four locations to represent typical cleanup areas (3 to 6 in Figure 39) and three locations next to the major noise sources (1, 2, and 7 in Figure 39). All measurements during followup visits to Plant B were made at the specified locations.

Table 25 presents a chronology of the retrofit installation and modifications and the schedule of followup visits between the

Measurement Location	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
	Sound Pressure Levels										
1. At secondary screen 2 ft from side plate 5 ft from discharge	107	88	95	93	95	100	101	103	99	91	81
2. At crusher feed 2 ft from hopper fifth step from top	106	84	88	94	96	101	102	100	96	89	81
3. Ground level	97	85	83	89	93	93	93	91	84	78	72
4. Ground level	98	84	82	89	90	93	95	92	87	79	72
5. Ground level	98	84	84	92	92	93	94	92	83	78	73
6. Ground level	98	84	87	88	90	92	95	90	84	78	74
7. At control panel 7 ft from motor (crusher) 2 ft from panel	96	83	87	89	89	92	91	86	82	74	67

Sketches, comments and notes

All measurements taken at waist level before retrofit.

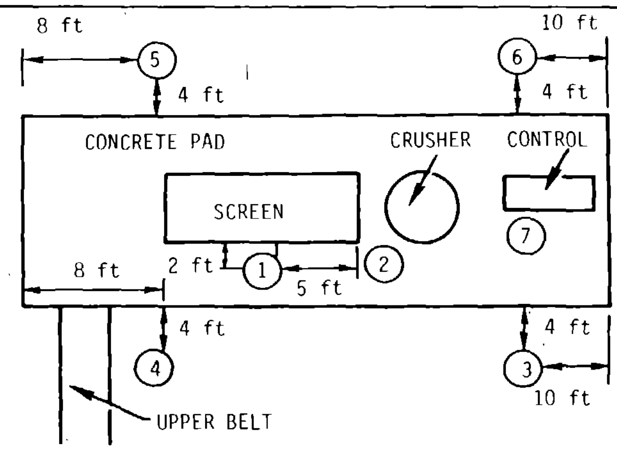


FIGURE 39. - Plant B - noise data base.

TABLE 25. - Plant B - retrofit chronology

Date	Retrofit number	Circuit condition	Noise treatment	Wear description
3/24/81	Before retrofit	5 × 14 ft DD Nordberg 20 deg inclined screen used to feed a 5100 standard cone crusher. Feed to plant from stockpiled jaw crusher product blended with sand. Feed -10 in. Screen moderately loaded and subject to random feed startup and shutdown, depending on load to tertiary stage. Top/bottom decks discharge into crusher. Accelerated large feed from chute across screen deck bouncing into crusher feed chute.	None.	-
3/26/81	1	Same as 3/24/81.	All treatment elements installed except crusher floating feed cone liners and noise curtain.	New materials.
4/7/81		Same as 3/26/81.	Same as 3/26/81.	Screen wing liners loose due to loose Hilti studs.
4/9/81	2	Same as 3/26/81 except automatic sand blender added.	Feed cone hopper and feed cone lined.	-
4/30/81		Same as 4/9/81.	Same as 4/9/81.	Very little wear. Slight dishing of screen feedbox liner and blind screen panel. Screen openings rounded at edges but very little wear and no blinding.
7/21/81		Same as 4/9/81.	Same as 4/9/81, not partially lined feed cone.	Two of seven feed cone liner elements, fell off and went through crusher. No damage to crusher.
7/21/81	3	Same as 4/9/81.	Crusher noise curtain installed on adjustment ring OD.	Same as 7/21/81, no obvious wear.
8/26/81		Same as 4/9/81.	Same as 7/21/81.	Same as 7/21/81, no obvious wear.
10/21/81	Final visit	Same as 8/26/81.	Same as 8/26/81.	Same as 8/26/81.

period of 24 March and 21 October 1982. Circuit conditions are briefly described as well as a summary of the observed deterioration of the installed treatments.

4.2.1 Initial Treatment

During the initial treatment installation on 26 March 1981, the following materials were installed:

a. Resilient screen feedbox linings

b. Resilient top deck

c. Resilient screen lip

d. Resilient liner in the crusher feed hopper

e. Resilient crusher feed plate

f. Resilient screen wing liners.

Noise measurements performed on 26 March 1981 showed a 9 dBA reduction at measurement location 1, which is 2 ft from the side plate of the secondary screen and 5 ft from the screen discharge lip. A 3 dBA reduction was observed at measurement location 5, which is at ground level near the screen. Little or no improvement was recorded at the other locations.

Figure 40 shows the octave band levels monitored at location 1 on 24 March (baseline), and on 26 March (screen modifications). As can be seen in Figure 40, significant reductions occurred in the 250 to 4000 Hz octave bands.

Refer to Appendix C for octave band and A-weighted sound levels that were monitored at the remaining locations on 24 March (baseline) and 26 March 1981, after the initial treatment.

4.2.2 Modification 2

On 9 April 1981, the crusher floating feed cone resilient liners were installed. Between 26 March and 9 April, the screen wing liners had become loose due to failure of the mounting studs. The wing liners were then bolted in place. Addition of the feed cone liners resulted in a 7 dBA reduction at the position 2 near the crusher feed. A four to five dBA reduction was measured at the operator's positions (measurement locations 3 through 7). Figure 41 shows the octave band noise levels monitored at position 2. As can be seen, the addition of the crusher feed cone liners significantly reduced the sound pressure levels in the 1000 to 4000 Hz octave bands. Similar reductions are evidenced at measurement location 5 as shown in Figure 42. Data for location 3 are shown in Figure 43.

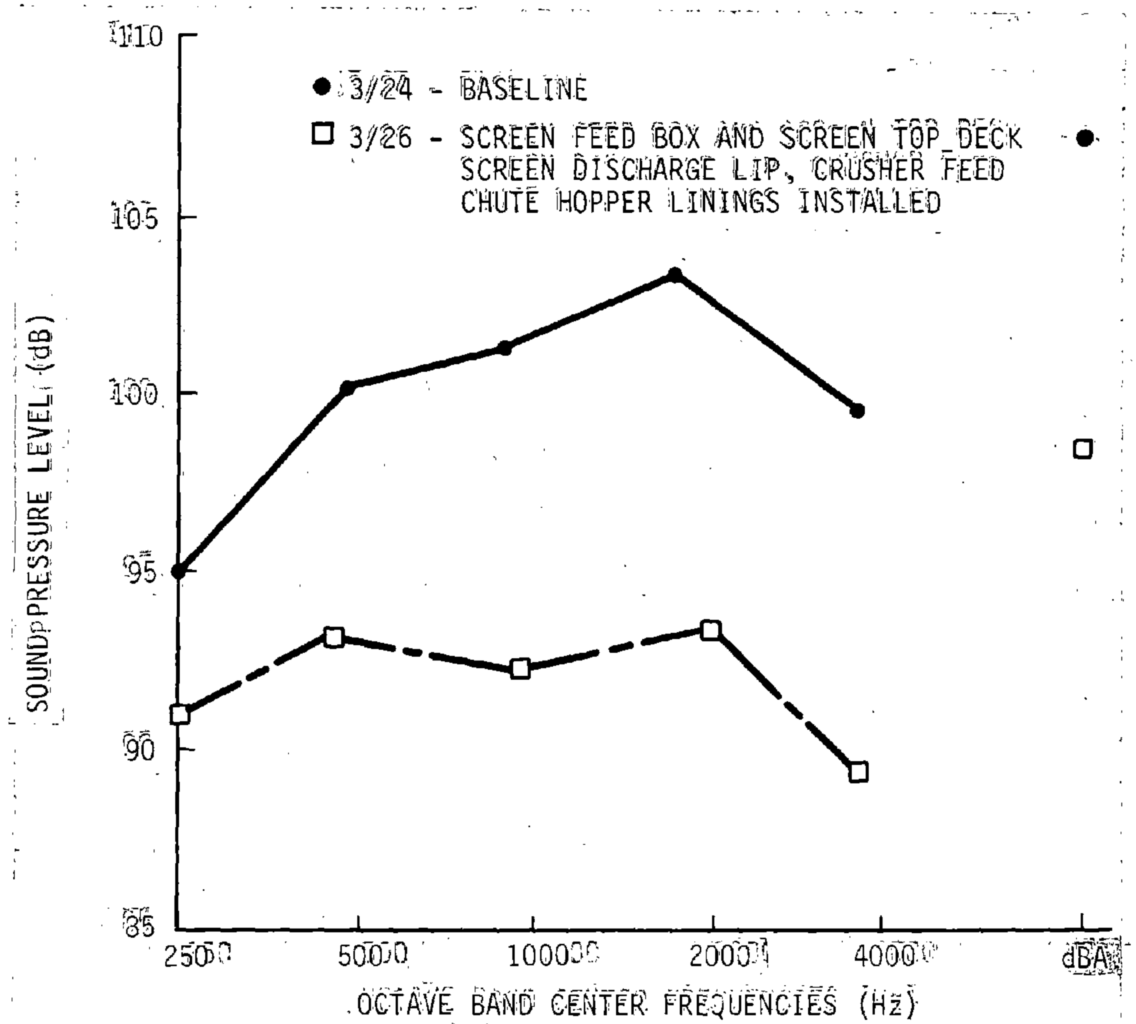


FIGURE 40. - Effects of retrofit treatments at Plant B - position 1 - beside screen.

Proofer ____________ Typist ____________

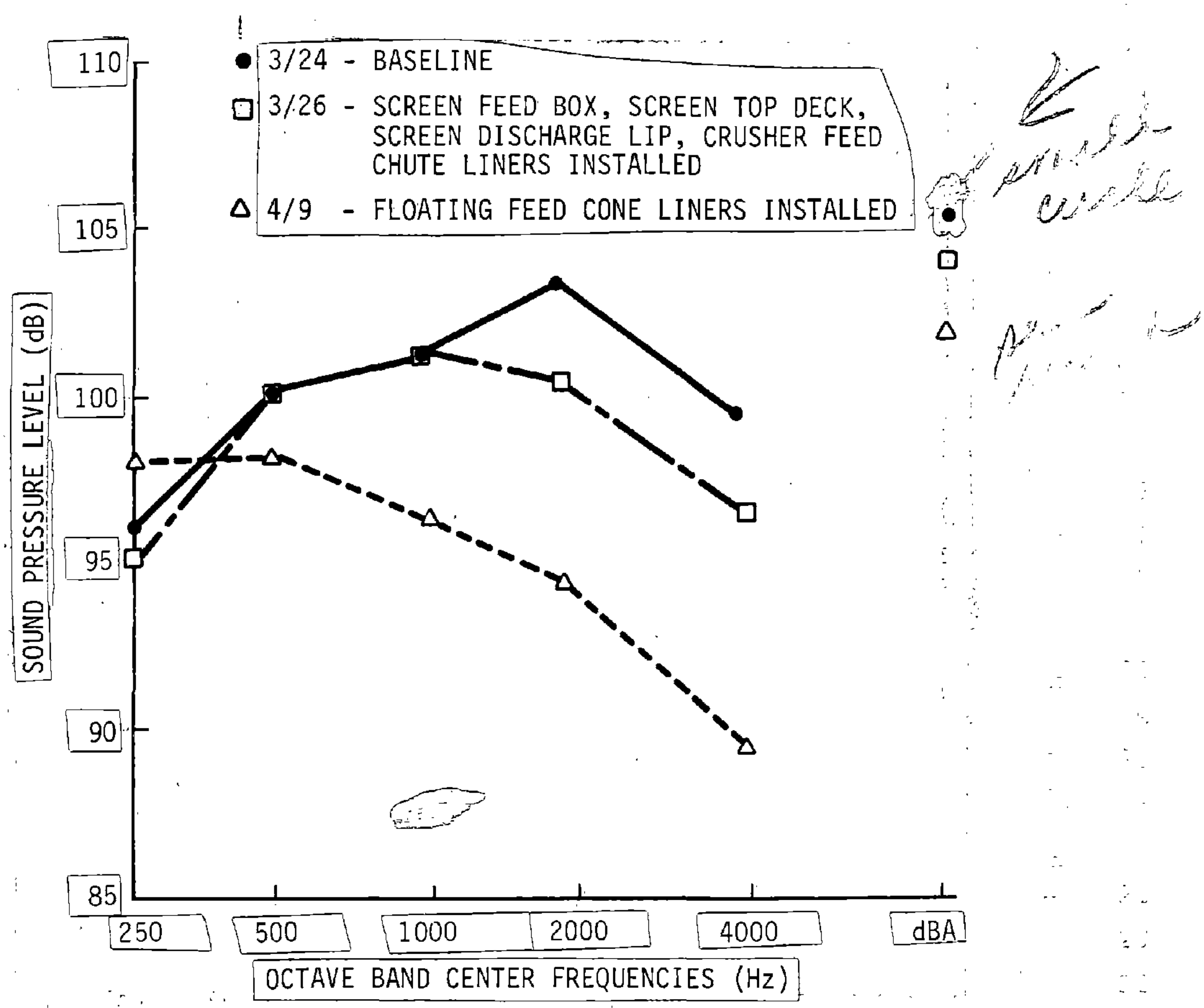


FIGURE 41. - Effects of retrofit treatments at Plant B - position no. 2 - screen discharge.

Proofer ____________ Typist ____________

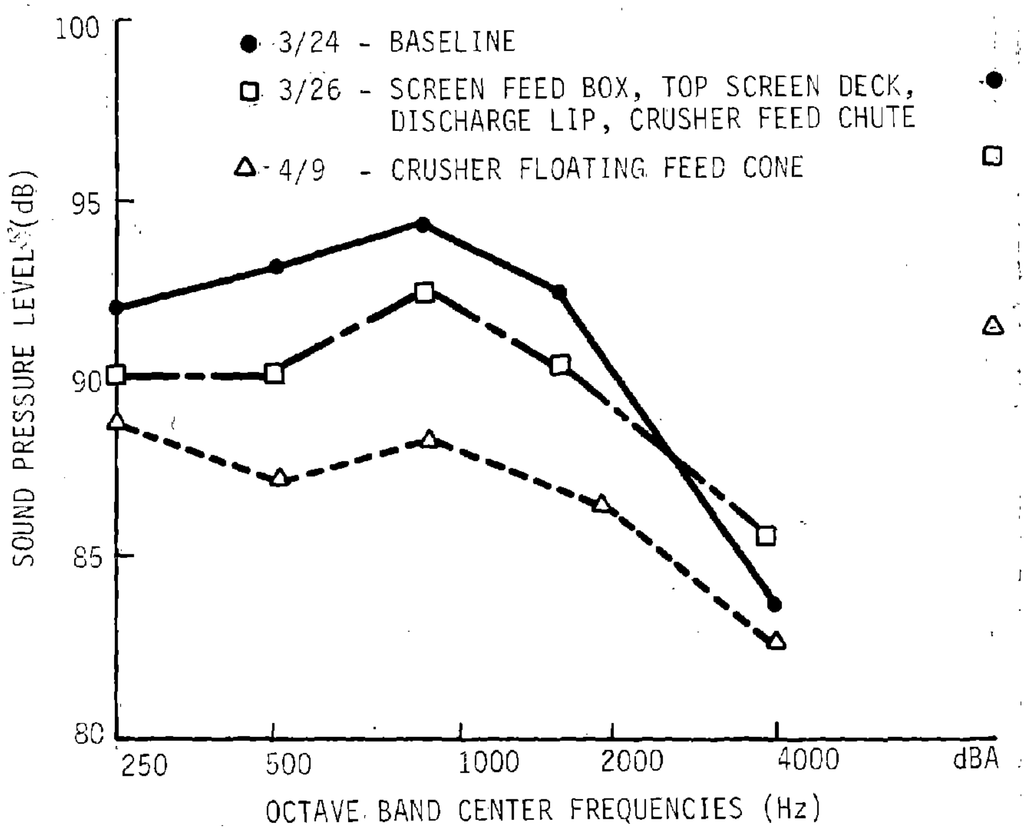


FIGURE 42. - Effects of retrofit treatments at Plant B - position no. 5 - ground level screen pad.

Proofer ____________ Typist ____________

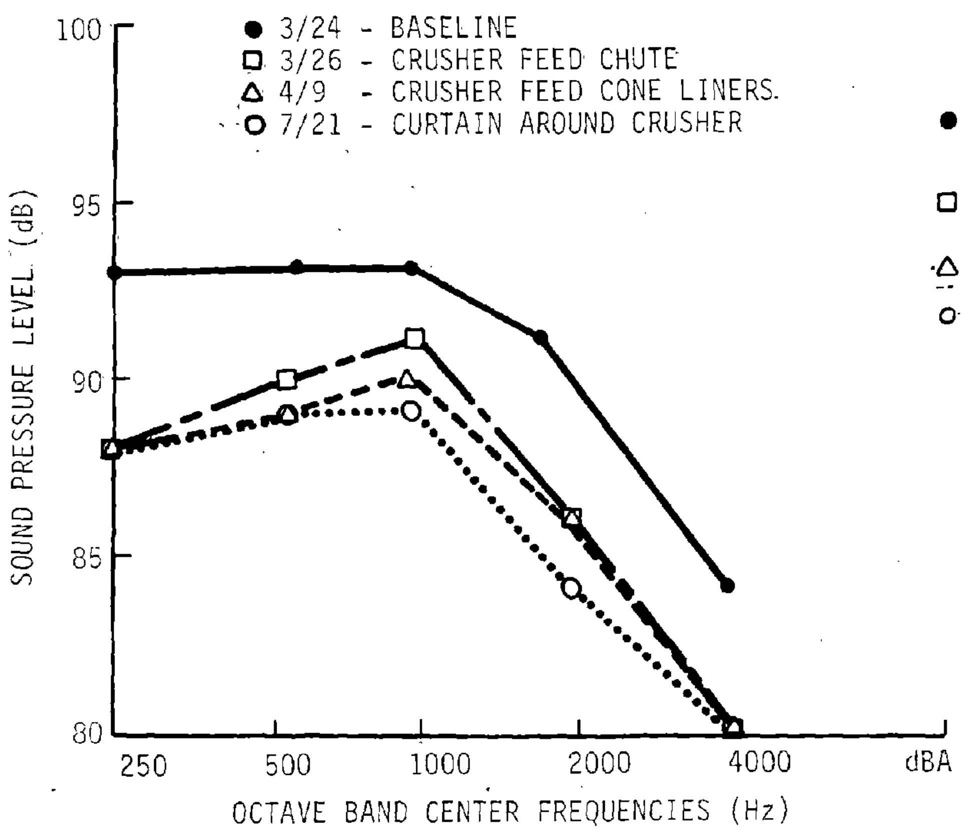


FIGURE 43. - Effects of retrofit treatments at Plant B - position no. 3 - ground level beside crusher.

Proofer ______ Typist ______

4.2.3 Modification 3

Between 9 April and 21 July 1981, two of the seven segments lining the crusher floating feed cone had broken loose and passed through the crusher. The decision was made to enclose the crusher shell while waiting for the replacement segments. Noise measurements performed after the curtain installation were the same as those measured on 9 April with the newly-installed crusher feed cone liners. The curtain appears to be as effective as the feed cone liner segments. The effectiveness of these treatments on reducing levels at typical operating positions is shown in Figure 43 for measurement position 3. Observation of other installed materials indicated that the screen feedbox liner and blind screen panel were showing slight wear patterns as was the screen discharge lip. The only other observed wear was a rounding of the edges of the screen openings.

4.2.4 Followup Visits

Additional followup visits to Plant B were conducted on 26 August and 21 October 1981. By 21 October, the quarry had processed 198,000 tons during the 28 weeks since the retrofit program had started.

Noise measurements performed on 21 October indicated little degradation of material performance at plant operating locations (measurement locations 3 to 7). Total noise reduction ranged from 3 to 7 dBA at the 5 locations.

By 21 October, most of the resilient materials were still showing minor wear. Figure 44 shows the resilient top screen deck, wing liners, and the crusher feed chute liner as viewed from the screen feed chute. A closeup of the feed end of the screen (Figure 45) shows some wear on the screen deck around the screen openings and the countersunk bolt holes. An additional closeup of the screen cloth is shown in Figure 46.

A closeup of the screen discharge is shown in Figure 47. Little, if any, wear is evidenced on the screen wing liners, bumper strip, side liner, or crusher feed chute liner. Dishing of the screen discharge lip liner is evidenced; however, it was felt that the liner had not and would not degrade to the point of replacement in the near future.

By 21 October, the original resilient crusher feed plate, supplied undersized by Trelleborg, had been replaced. The worn-out feed plate is shown in Figure 48. As can be seen, the

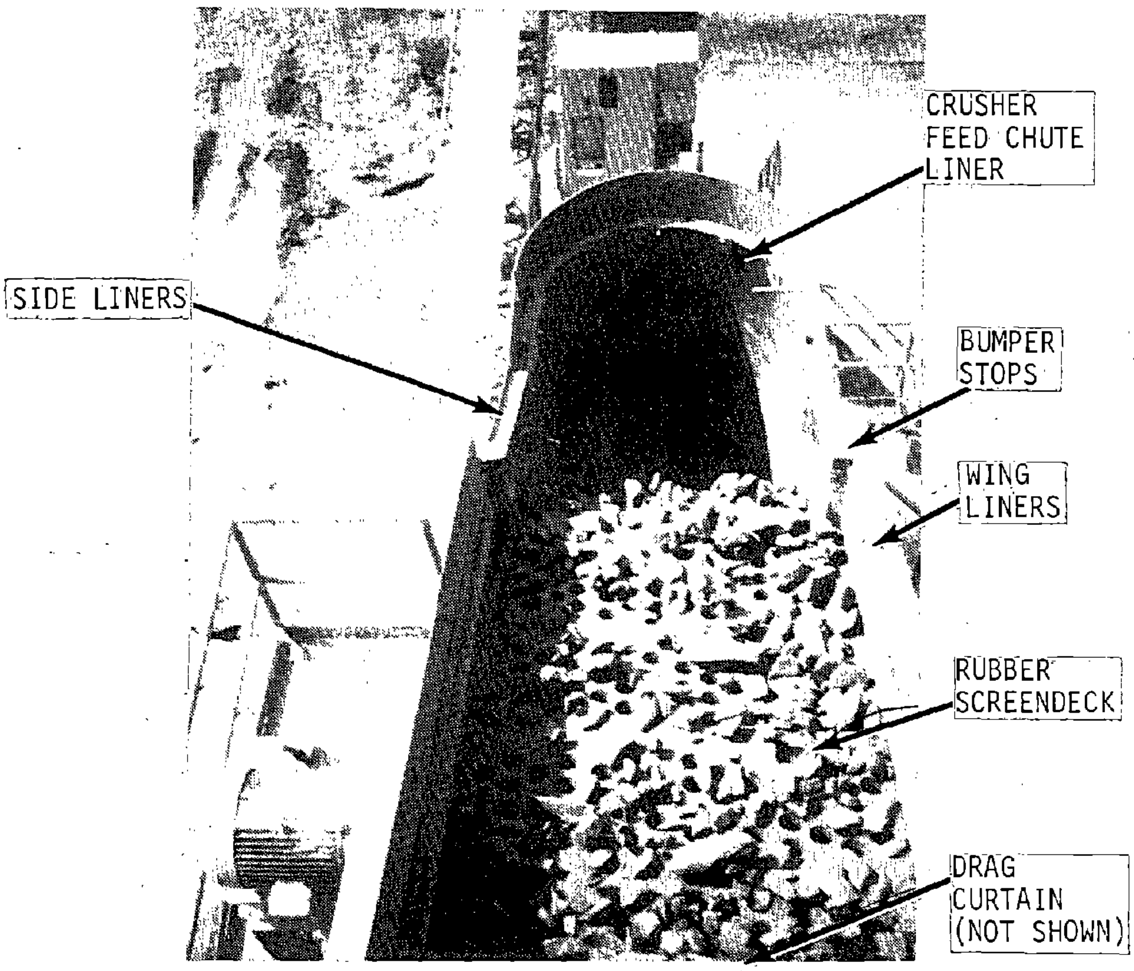


FIGURE 44.—Plant B screen area.

Proofer Typist

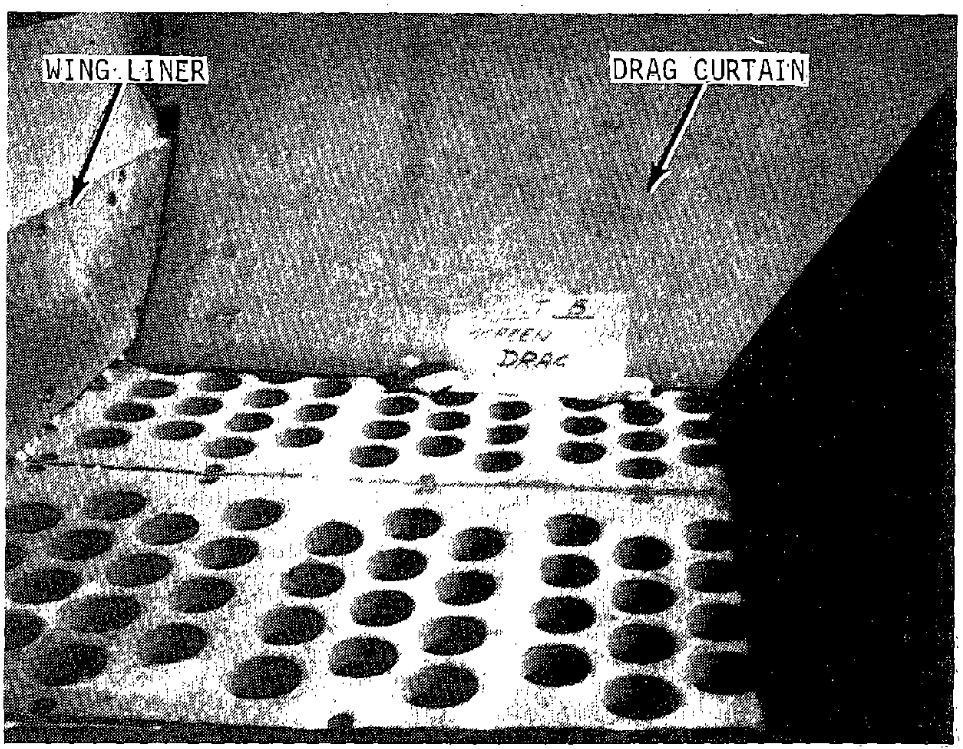


FIGURE 45. - Plant B screen feed end.

FIGURE 46. - Plant B screen cloth, typical condition.

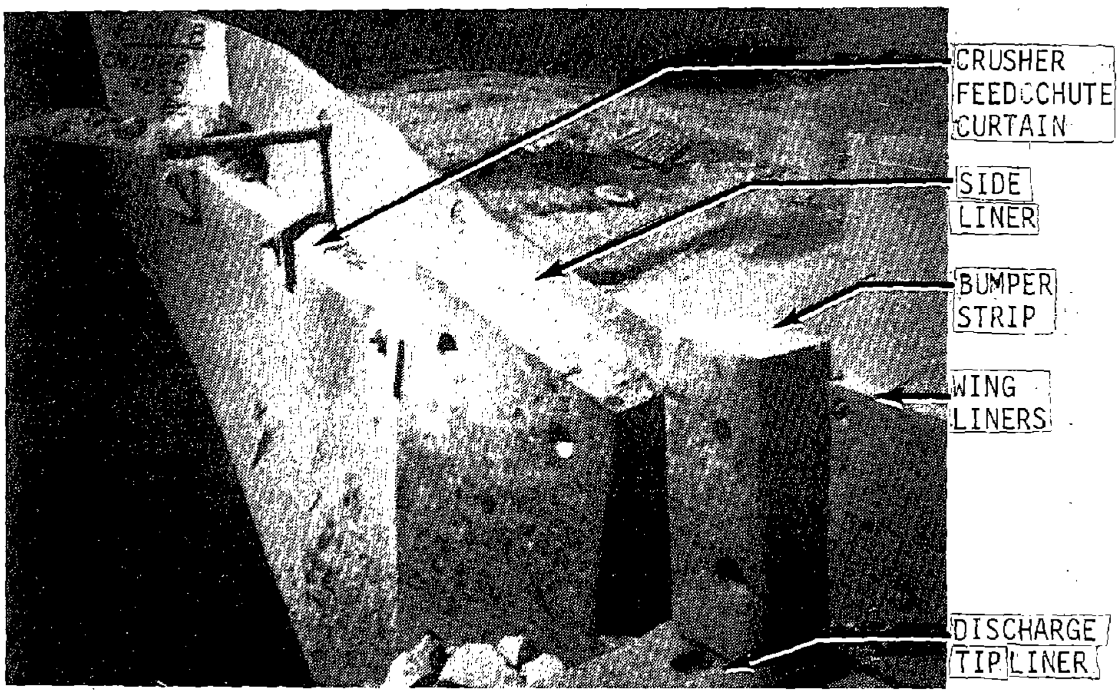


FIGURE 47. - Plant B screen discharge area.

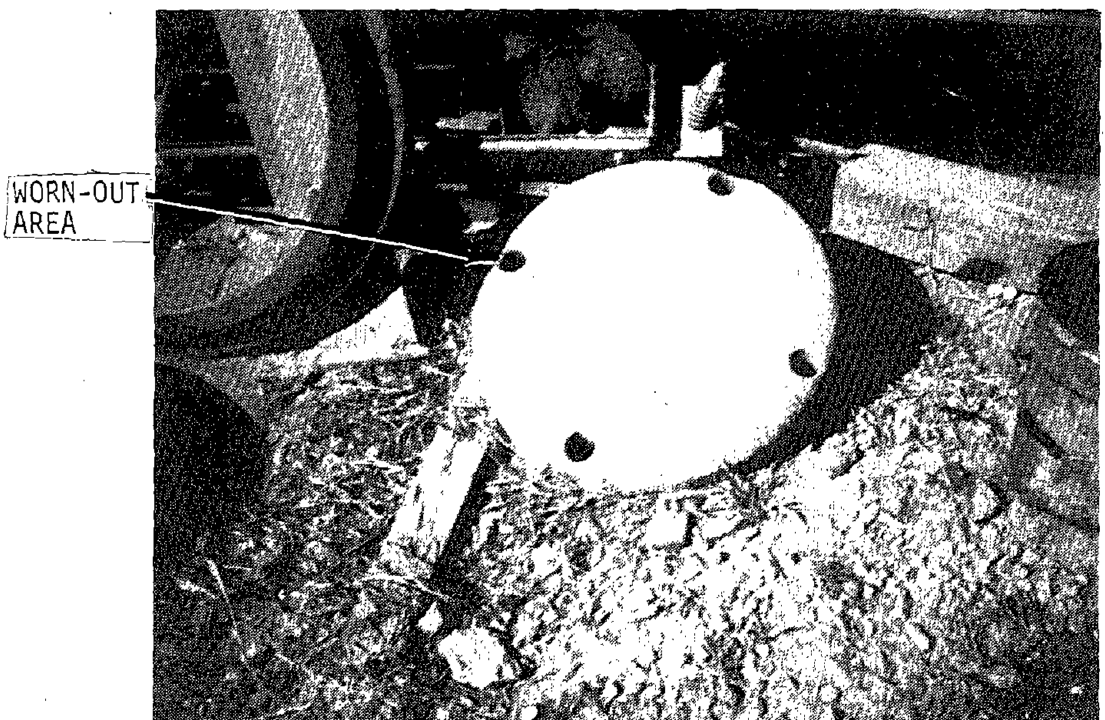


FIGURE 48. - Worn crusher feed plate - Plant B.

problem with the original plate was caused primarily by failure of the material between the bolt holes and the outside diameter of the plate. The replacement plate (shown in Figure 49) was manufactured 3 in. in diameter larger. By the final followup visit, the new plate had only been in service for 4 weeks.

The curtain installed around the crusher shell is shown in Figure 50. During the final visit, little, if any deterioration of the curtain could be observed after 3 months of operation.

4.2.5 Summary

During the period of 24 March to 21 July 1981, the following retrofit noise control treatments were installed:

a. Resilient screen feedbox liner

b. Resilient top screen deck

c. Resilient screen wing liners

d. Resilient screen discharge lip

e. Resilient liner in the crusher feed chute

f. Resilient crusher feed plate

g. Resilient crusher feed cone liners

h. Curtain around the crusher shell.

All materials were supplied by Trelleborg. Noise reductions of 3 to 7 dBA were achieved at five selected operating locations around the base of the plant. These reductions have resulted in an average doubling of the allowable exposure time for plant operating personnel.

By the end of the monitoring phase of this program, the materials were showing little wear after processing 198,000 tons. While the total life of the materials is hard to predict, the vendor has guaranteed the life of the screen cloth for 1,500,000 tons.

4.3 Plant B - Primary Crusher Control Booth

The control booth for the primary crusher operator at Plant B was installed on 25 November 1980. Noise measurements performed after the installation indicated that noise levels inside the

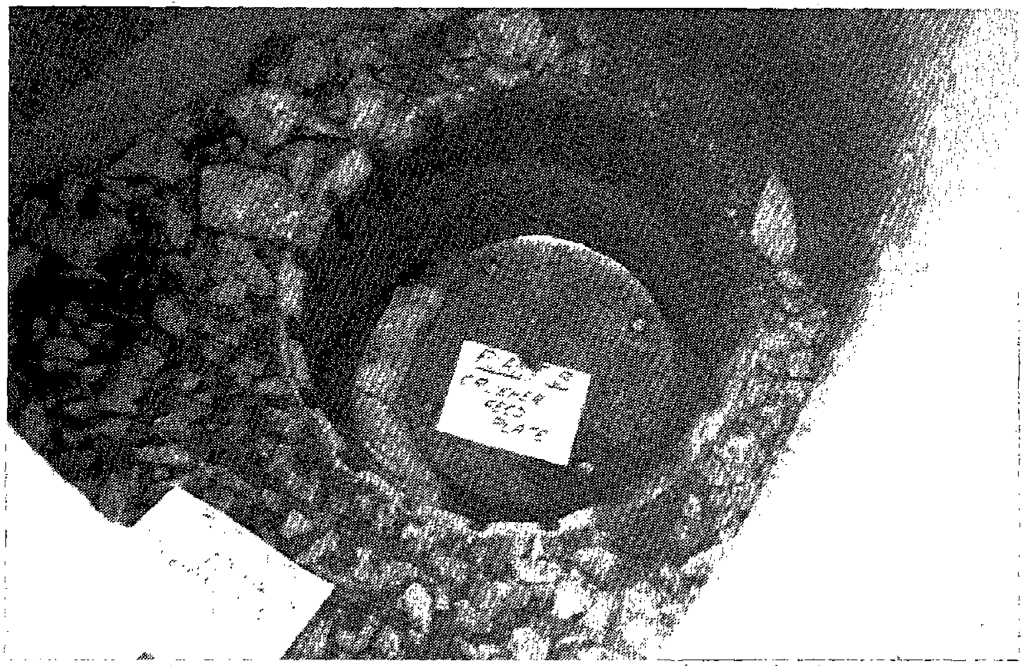


FIGURE 49. - Plant B - crusher feed area.

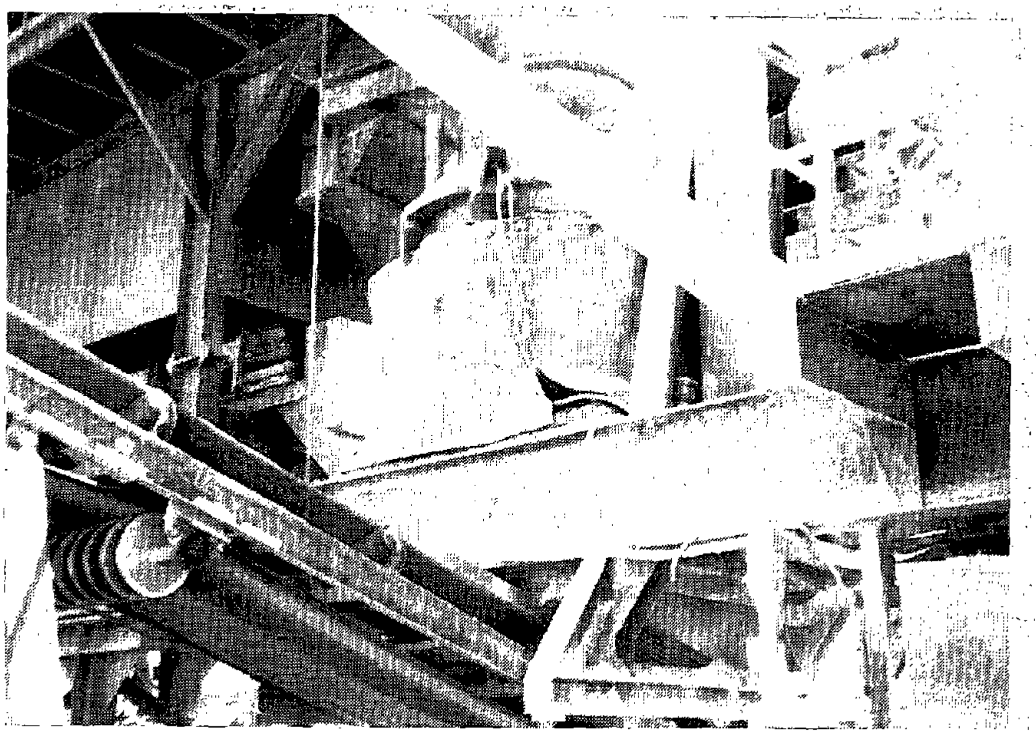


FIGURE 50. - Plant B - crusher noise curtain.

booth were less than 80 dBA. Noise levels measured on the catwalk over the crusher were 97 dBA. Octave band analyses for the two measurement locations are shown in Table 26.

A view of the booth interior showing the primary crusher operator during normal plant operation is shown in Figure 51. From the position shown, the operator has an unobstructed view of the crusher feed and other plant components.

Performance of the booth was monitored during each of the followup visits to Plant B. During this period, program team members monitored noise levels and the work practices of the operator. By 21 October 1981, the last followup visit, noise levels inside the booth were still less than 80 dBA and no deterioration in the physical condition of the booth had occurred.

4.4 Plant A and Plant B Treatment Costs

Table 27 presents the noise control treatment costs for Plants A and B. Costs include actual capital costs in 1981 dollars and actual installation costs in manhours expended for the retrofits.

Capital items totalled $17,085 and $14,000 for Plants A and B, respectively. Plant A items took 69 manhours to install, and Plant B items took 66 manhours to install.

The primary crusher control booth at Plant B cost $4919 delivered, and it required 40 manhours to install.

Plant A resilient screen panels cost $0.03 per ton processed as compared to a normal cost of $0.0046/ton for the steel plate they replaced. Plant B resilient screen panels are still in service with a guaranteed life of 1,500,000 processed tons or about 3 times the life of steel plate. If the guaranteed life is reached, the cost will be $0.0049/ton processed, which will be competitive with steel plate and at lower noise levels.

Treatment costs were held to about 5 to 7 percent of the estimated cost of a new 200 to 300 tons/hr portable plant, or about $13,000 to $18,000. It has been Foster-Miller's experience that reasonably maintained portable operations invest approximately that amount annually *in the items addressed by this program plus wear materials*. Often these costs are hidden by spontaneous makeshift repairs, or new replacement parts (for example, new floating feed cone assembly, new feed plate, etc.)

TABLE 26. - Plant B - jaw crusher operator's noise control booth - sound pressure level measurements of 11 November 1980

	Sound pressure levels										
Measurement location	A	31.5	63	125	250	500	1000	2000	4000	8000	16,000
Inside primary crusher booth - door closed	78	85	86	80	74	70	68	65	60	49	39
Inside booth - door open	93	83	93	91	93	88	86	79	73	68	62
Above primary crusher	97	86	100	94	98	97	90	82	72	67	64

FIGURE 51. - Plant B - primary crusher control booth.

but the costs are there nonetheless. If these items are equally cost-effective with their AR material counterparts *and* also attenuate the ambient noise levels, then the goals of the program have indeed been met. The performance versus cost of the rubber elements designed for the retrofit portion of this program has led Foster-Miller to the conclusion that there are reasonable economics in retrofit noise treatment for portable plants.

New portable plant cost-tradeoffs are possible. The substitution of resilient materials for the currently used AR metals by the OEM might have a minimal first-cost impact but will potentially improve the plant maintainability. When a new plant is being manufactured, resilient materials can be incorporated in normally hard-to-reach component or chassis areas. Additionally, material transfer points often can be addressed by standard design practices without increasing costs to the customer. The basis for this type of cost-effective noise treatment program has been established with this research.

TABLE 27. - Noise control treatment costs

Plant	Item	Material	Capital, $ (plus shipping)	1981 Costs Installation manhours	$ per ton processed	Time in service Weeks (approx.)	Processed tonnage	Comments
A	1. Conveyor discharge impact pad	2 in. *reinforced* urethane	354	2.0	0.008	3	44,360	
	2. Feed conveyor discharge box liner	2 in. urethane screen panel	1,225	2.5	< 0.01	8	117,800	In service, badly worn.
	3. Screen feedbox liner	2 in. reinforced urethane	400	1.0	< 0.002	11	165,000	In service
	4. Screen panels: 4 at 3 in. square	2 in. reinforced urethane	4,900	20.0	0.03	11	159,840	Steel plate = $0.0046/ton *average tons* = 680,000
	5. Hold down/side tension parts	steel coated urethane	584	Included in no. 4	0.003	Removed with screen cloth		
	6. Screen discharge lip side liner	1-1/2 in. reinforced urethane	642	1.5	< 0.004	11	160,000	In service, badly worn.
	7. Screen discharge lip liner	1-1/2 in. reinforced urethane	550	1.0	< 0.003	11	160,000	In service, badly worn.
	8. Screen panels: 4 at 1-1/2 in. square	1-1/2 in. *reinforced* urethane	6,292	30.0	< 0.03	17	212,520	In service, badly worn.
	9. Screen side protection rails	Urethane	338	1.0	0.012	2	28,500	Rapid wear - large *material*.
	10. Conical hopper liner	1 in. reinforced urethane	1,800	10.0	< 0.005	24	382,000	In service, badly worn.
	TOTALS		$17,085	69.0	< 0.107			
B	1. Screen feedbox liner	3-1/8 in. rubber on plate	615	2.0	See footnote no. 1	28	197,840	
	2. Blank screen panel	3 in. reinforced rubber	1,470	1.5		28	197,840	
	3. Screen panels (6)	2 in. reinforced rubber	5,960	11.0		28	197,840	Includes $320 setup charge
	4. Screen side wings	1 in. rubber on plate	612	2.5		28	197,840	
	5. Screen discharge lip	2 in. *rubber on plate*	420	1.5		28	197,840	
	6. Crusher feed chute liners	3-1/8 in. rubber on plate		3.0		28	197,840	
	7. Crusher feed chute curtain	1 in. rubber	1,810	6.0				
	8. Curtain mounting bar	Rolled steel	45	1.5		28	197,840	
	9. Molded crusher feed plate	5 in. rubber plate	600	3.0		4	≃ 50,000	
	10. Floating feed cone liner	1 in. rubber on plate	1,084	30.0		24	≃ 100,000	Supplied in small segments
	11. Crusher curtain	lead lined vinyl	462	3.0		4	40,000	
	12. Eyelets for no. 11	3/4 in. grommets	125					
	13. Screen drag curtain	2 in. rubber	800	1.0		27	180,000	Retards bouncing feed.
	TOTALS		$14,003	66.0				Service continuing

[1] All items still in service (7 December 1981) *except segments* of Item No. 10. Therefore cost per ton not recorded. Trelleborg guarantees 1.5 · 10^6 tons.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Treatment techniques employed the use of advertised commercially available resilient wear materials that could be applied practically by both the smallest and largest operations. Treatment costs for the portable plants were kept to about 5 to 7 percent of the purchase price of a new 200 to 300 ton/hr plant. Reasonably maintained plants invest this amount annually to keep the material handling and transfer points in good shape. Care was taken not to adversely affect the performance of the comminution circuit or the equipment utilized in the circuit. The achieved wear performance and noise reduction versus the cost of the rubber products utilized during this program have led Foster-Miller to conclude that ~~retrofit noise~~ modifications can be economically applied to portable plants.

It is also reasonable to assume that new portable plants can incorporate this technology into their manufacturing process and address additional noise sources. A retrofit program can only address field-accessible areas, but new plants can be designed and fabricated to incorporate resilient materials for improved wear and noise control. New plant cost-tradeoffs are possible when wear-resistant resilient materials are substituted for AR metals. The justification for incorporating cost-effective noise treatments in portable plants, without substantially affecting productivity in the secondary circuit, has been established with this program.

5.2 Future Research Recommendations

The mining community is cost and production-sensitive. More objective research is necessary to provide credibility for the use of resilient materials as a reasonable substitute for AR metals and woven wire cloth. This program addressed secondary crushing/screening plants which were essentially scalping a dry, coarse product prior to secondary crushing.

5.2.1 Screening Efficiency

Normally, secondary plants are not production-sensitive and the use of resilient screen decks with coarse openings usually does not affect the circuit. However, tertiary and quarternary stages can be dramatically affected by using resilient cloth. The inherent

Proofer ________ Typist ________

problem involving the use of resilient cloth in these stages is the reduction in the screen deck's percentage of open area. Using existing screen sizing technology when trying to utilize resilient cloth as the screening media suggests to the industry that a larger screen is necessary to process the same amount of material effectively. The screening efficiency of substitute resilient cloth versus wire cloth should be explored further before a recommendation is made that resilient cloth is a viable noise control technique, especially in tertiary and quarternary plants.

5.2.2 Wear Materials

The wear properties of resilient materials have only been touched on in this program. This report has presented both the success and failure of different materials used in the processing of a hard, dry, coarse granite. A wet-screening operation processing limestone or sand and gravel could produce different results. It is necessary to perform either an objective, statistically-representative sampling of the industry covering the actual use of resilient materials or a controlled laboratory wear materials test program in order to confirm the wear properties of both urethane and rubber products.

5.2.3 New Portable Crushing and Screening Plants

The techniques employed in this program are directly applicable to new portable plants. They can be incorporated and improved upon when they are included during the design and fabrication of a new plant before it goes into service. Foster-Miller feels confident that rubber products can be utilized in the design of a new secondary portable cone crusher plant to control the noise at both the sources addressed by this program and at other normally inaccessible locations. Based on the results of this program, it is reasonable to expect that the techniques which have been demonstrated in this retrofit program would result in both lower noise levels and reduced maintenance when applied to the design of a new plant.

Proofer ______ Typist ______

APPENDIX A

DOSIMETER TEST RESULTS

The results of the dosimeter tests are presented in Tables A-1 through A-7.

TABLE A-1. - Dosimeter results - plant A

Worker	Percent of allowable exposure
Plant Foreman	40.81*
Cleanup Man	48*

*Extrapolated from a 3-1/2 hr survey.

TABLE A-2. - Dosimeter results - plant B

Worker	Percent of allowable exposure
Foreman	80*
Primary Crusher Operator	325*

*Extrapolated from a 3-hr survey.

TABLE A-3. - Dosimeter results - plant C

Worker	Percent of allowable exposure
Primary Operator	26*
Secondary Screen Operator	312*

*Extrapolated from 3-hr survey.

TABLE A-4. - Dosimeter results - plant D

Worker	Percent of allowable exposure
Quality Control and Cleanup	133*
Laborer	163*

*Extrapolated from 3-hr survey.

TABLE A-5. - Dosimeter results - plant E

Worker	Percent of allowable exposure
Plant Operator	51*
Cleanup Man (also drives haulage trucks)	251*

*Extrapolated from 6-hr survey.

TABLE A-6. - Results of dosimeter survey - plant F

Worker	Percent of allowable exposure
Cleanup Man - Primary Crusher	412*
General Cleanup Man	399*

*Extrapolated from 3.3-hr survey.

TABLE A-7. - Dosimeter survey results - plant H

Worker	Percent of allowable exposure
Plant Operator	188*
Plant Supervisor	21*

*Extrapolated from 3.3 and 4.2-hr surveys, respectively.

APPENDIX B

PLANTS A THROUGH H: A-WEIGHTED NOISE LEVELS (dBA)

The results of the A-weighted noise level surveys for plants A through H are presented in Tables B-1 through B-8.

TABLE B-1. - A-weighted noise levels - plant A

Measurement location	Level (dBA)	Comments
1. Outside main operator's booth	92	
2. Inside operator's booth	73	
3. Secondary module		
a. On the ground at secondary screen conveyor discharge	96	
b. On the ground at the secondary crusher conveyor discharge	98	
c. On catwalk next to secondary screen	112	Workers did not spend time here while the plant was operating
d. On catwalk next to secondary crusher	111	
4. Tertiary module		
a. On ground at tertiary screen discharge	95	
b. Same as a. but without feed	92	
c. On catwalk next to tertiary crusher	109	Workers did not spend time here while the plant was operating
d. On catwalk next to tertiary screen	109	

TABLE B-2. - A-weighted noise levels - plant B

Measurement location	Level (dBA)	Comments
1. Jaw crusher		
a. On catwalk over jaw crusher feed	101	
b. Inside jaw crusher operator booth	85	
2. Secondary module		
a. At tail pulley of secondary crusher discharge conveyor	96	Normal cleanup area
b. At hydraulic adjustment panel for secondary crusher	94	
c. On catwalk beside secondary screen	113	Workers did not spend time here while plant was operating
d. Over secondary crusher	108	
3. Tertiary module		
a. On ground at tertiary crusher discharge	101	Normal cleanup area
b. At hydraulic adjustment panel for tertiary crusher	96	
c. On catwalk beside tertiary screen	106	Workers did not spend time here while plant was operating
d. Over tertiary crusher	108	
4. Main operating booth		
a. Outside	94	
b. Inside	71	

TABLE B-3. - A-weighted noise levels - plant C

Measurement location	Level (dBA)	Comments
1. Jaw crusher		
a. Over jaw crusher	108	
b. Next to jaw crusher discharge	100	
c. Inside operator's booth	83	
2. Secondary screen tower		
a. Between two screens	106	Screen operator spends entire shift on this tower
b. Beside one screen	106	
c. Inside secondary screen control booth	95	
3. Tertiary crushers		
a. Over tertiary crushers	101	
b. At second stage screen discharge chute	102	
4. Tertiary screen tower - on catwalk	101	
5. Fourth stage crusher discharge chute	92	
6. Outside main control building	87	

TABLE B-4. - A-weighted noise levels - plant D

Measurement location	Level (dBA)	Comments
1. Jaw crusher		
a. On catwalk over primary crusher	105	
b. Inside primary crusher operating booth	80	
2. Secondary crushing plant		
a. At feed to secondary crusher	115	
b. On catwalk next to secondary screen	108	
c. Between secondary and tertiary plants	91	
3. Tertiary plants (crushing and screening are separate)		
a. At tertiary crusher feed	103	
b. On catwalk, tertiary screen tower	107	
c. At rock box and discharge chute at base of tertiary screen	102	

TABLE B-5. - A-weighted noise levels - plant E

Measurement location	Level (dBA)	Comments
1. Primary crusher		
a. Over primary crusher feed	95	
b. Inside primary crusher control booth	71	
2. Secondary module		
a. At base of crushing and screening module	99	
b. On operator's platform	110	
c. At bin adjacent to operator	103	
d. Platform at secondary screen	113	
3. Tertiary crushing module		
a. On operator's platform	104	
b. Base of crusher module	91	
4. Platform near tertiary screen, on tower	110	
5. Blending bins		
a. Near bin coarse blending area	100	Survey of these bins was requested by the plant operator
b. Near bin fine blending area	90	
c. Inside bin operator booth - door open	88	
d. Inside bin operator booth - door closed	75	

TABLE B-6. - A-weighted noise levels - plant F

Measurement location	Level (dBA)	Comments
1. Primary crushers (2)		
a. Outside primary crusher operator's booth	98	
b. Inside primary crusher operator's booth	72	
c. Outside electricians shelter, near primary crusher	94	
2. Tertiary cone crushers		
a. At base of 4-1/4 ft secondary crusher	104	
b. Catwalk between the 4-1/4 ft and the 4-ft crushers	100	
3. Secondary impact crusher		
a. Next to crusher	104	
b. Clean up area at base of crusher	100	
4. Williams impact crusher		
a. At base of Williams Impactor	87	
b. Operator platform	94	
5. Main screen tower		
a. Near A.C. 6 ft × 16 ft screen	110	
b. At transfer chute	106	
6. Tertiary screen (8 ft × 20 ft Tyler)		
a. Catwalk next to screen	100	
b. Base of screen	95	

TABLE B-7. - A-weighted noise levels - plant G

Measurement location	Level (dBA)	Comments
1. Primary crusher		
a. Operator's stand	102	
b. Cleanup area under primary crusher	99	
c. At transfer conveyor	92	
2. Secondary module		
a. On catwalk next to secondary screen	109	
b. Under crusher platform	106	
c. Under screen deck and secondary crusher	103	
3. 50 ft from both primary and secondary	90	

TABLE B-8. - A-wighted noise levels - plant H

Measurement location	Level (dBA)	Comments
1. Primary crusher		
a. On catwalk next to primary crusher	100	
b. Transfer chute: secondary crusher discharge to primary discharge conveyor	91	
2. Secondary crushing plant		
a. Operator's area above screen	101	
b. Inside operator's booth	93	
c. At secondary crusher	110	No one spends time here
d. Under secondary crushing plant near cleanup area	92	
3. Wash tower screen		
a. At screen tower	101	
b. Under wash tower in cleanup area	92	
4. Center of plant 40 ft from each module	90	

Proofer ____________ Typist ____________

APPENDIX C

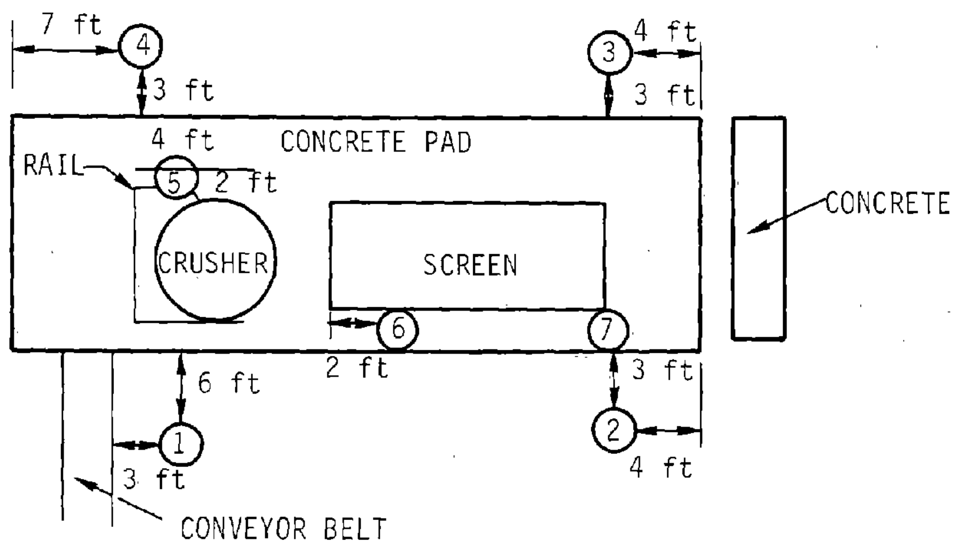
PLANT A AND PLANT B

Sound Pressure Levels Before and After Treatment

and

A-Weighted Sound Levels Before Treatment and Best Improvement

Figures C-1 through C-14 present information for Plant A. Figures C-15 through C-24 present information for Plant B.



POSITIONS 1, 2, 3, 4	=	GROUND LEVEL
POSITION 5	=	AT CRUSHER LEVEL ADJACENT TO THE FEED HOPPER
POSITIONS 6, 7	=	TOP SCREEN DECK LEVEL

FIGURE C-1. Plant A - measurement locations.

Proofer ______________ Typist ______________

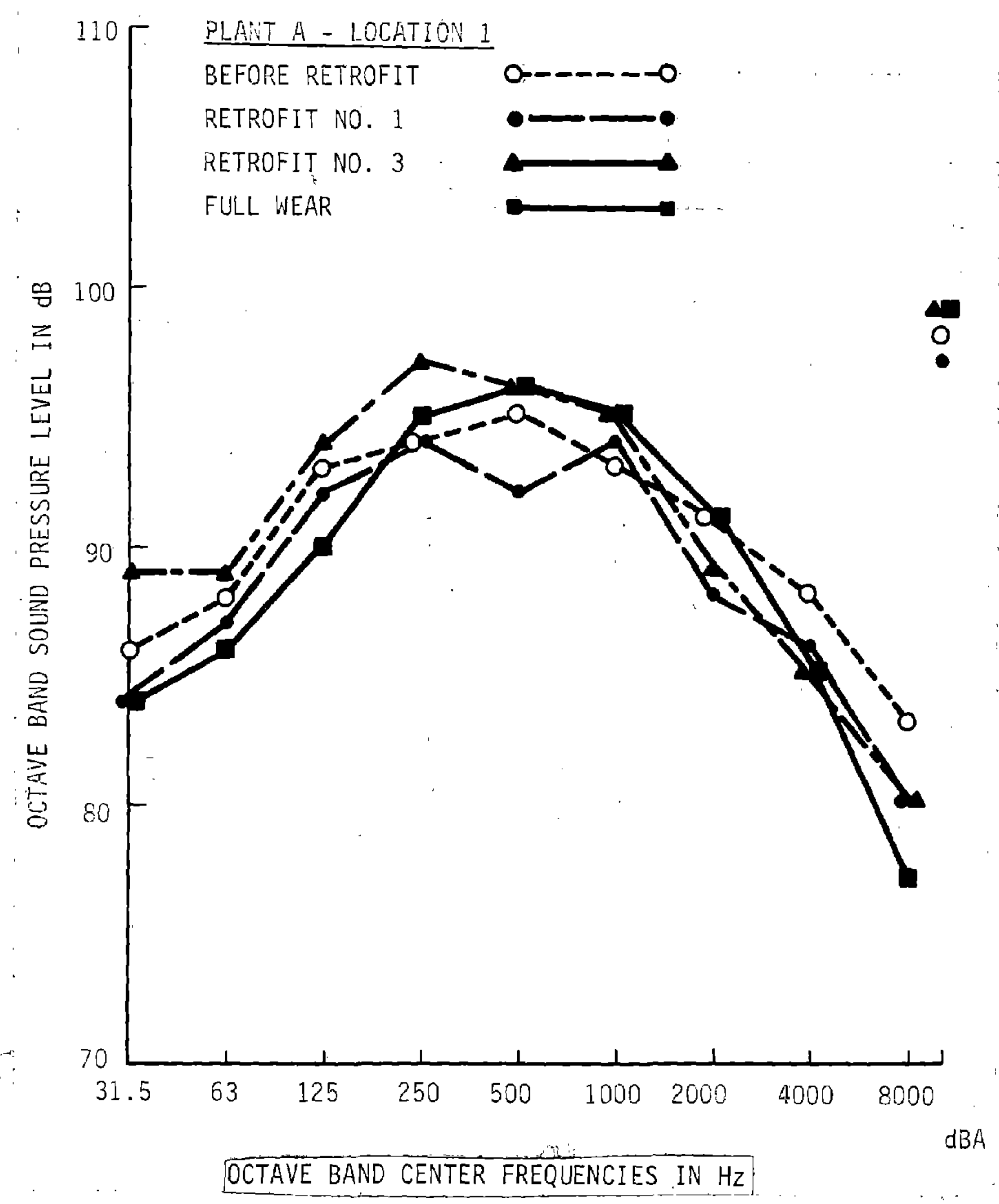


FIGURE C-2. - Sound pressure levels before and after treatment.

Proofer ______________ Typist ______________

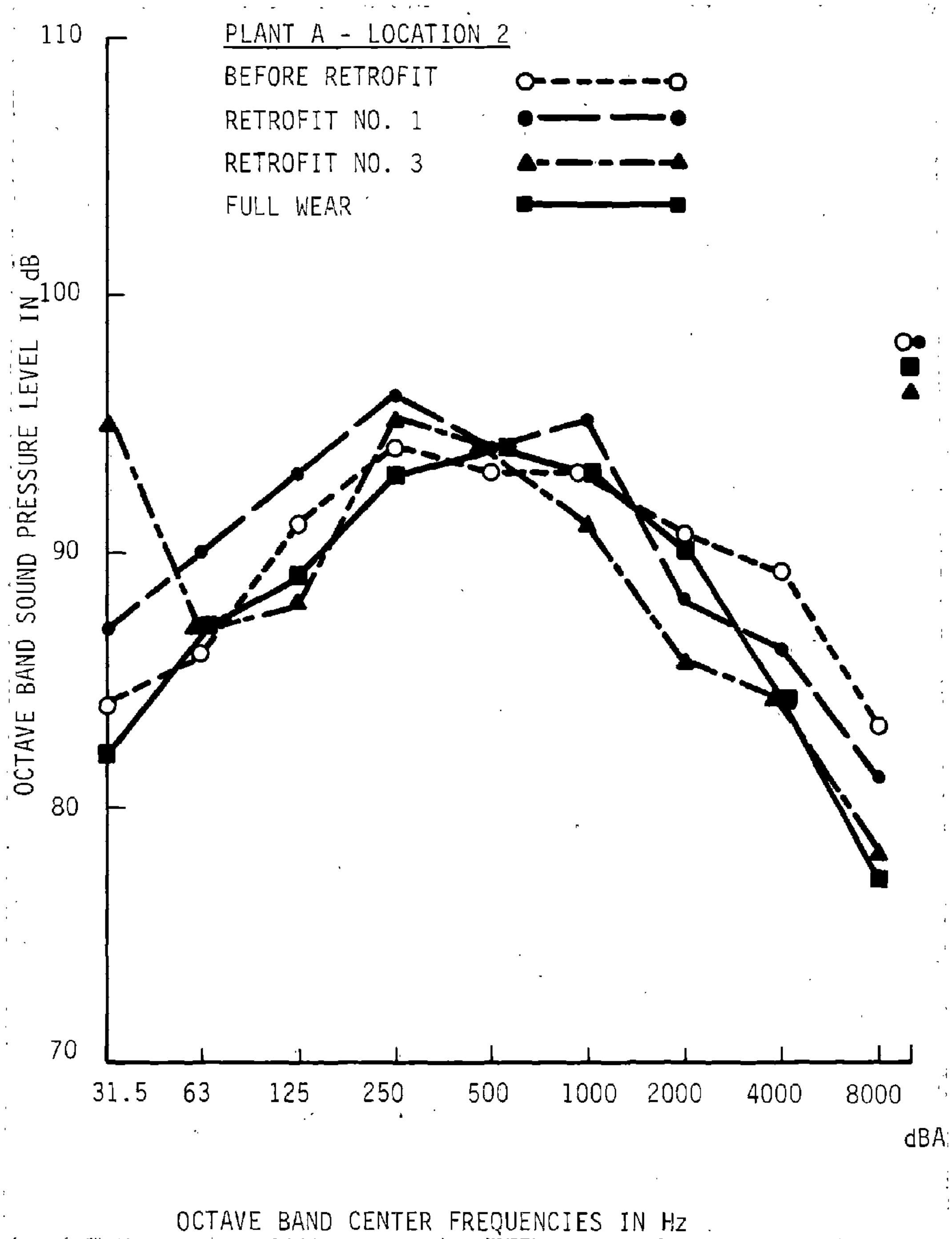


FIGURE C-3. — Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

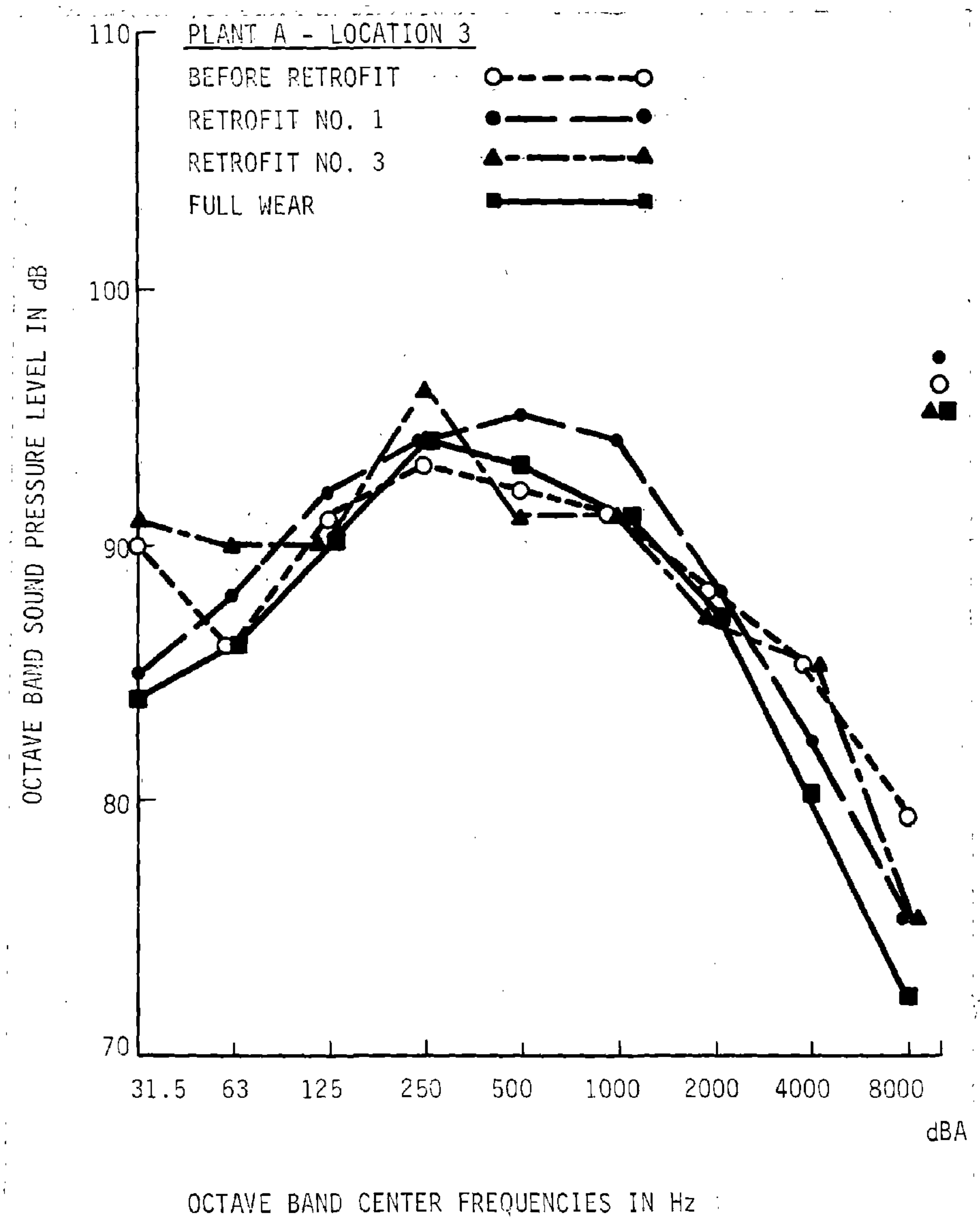


FIGURE C-4. Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

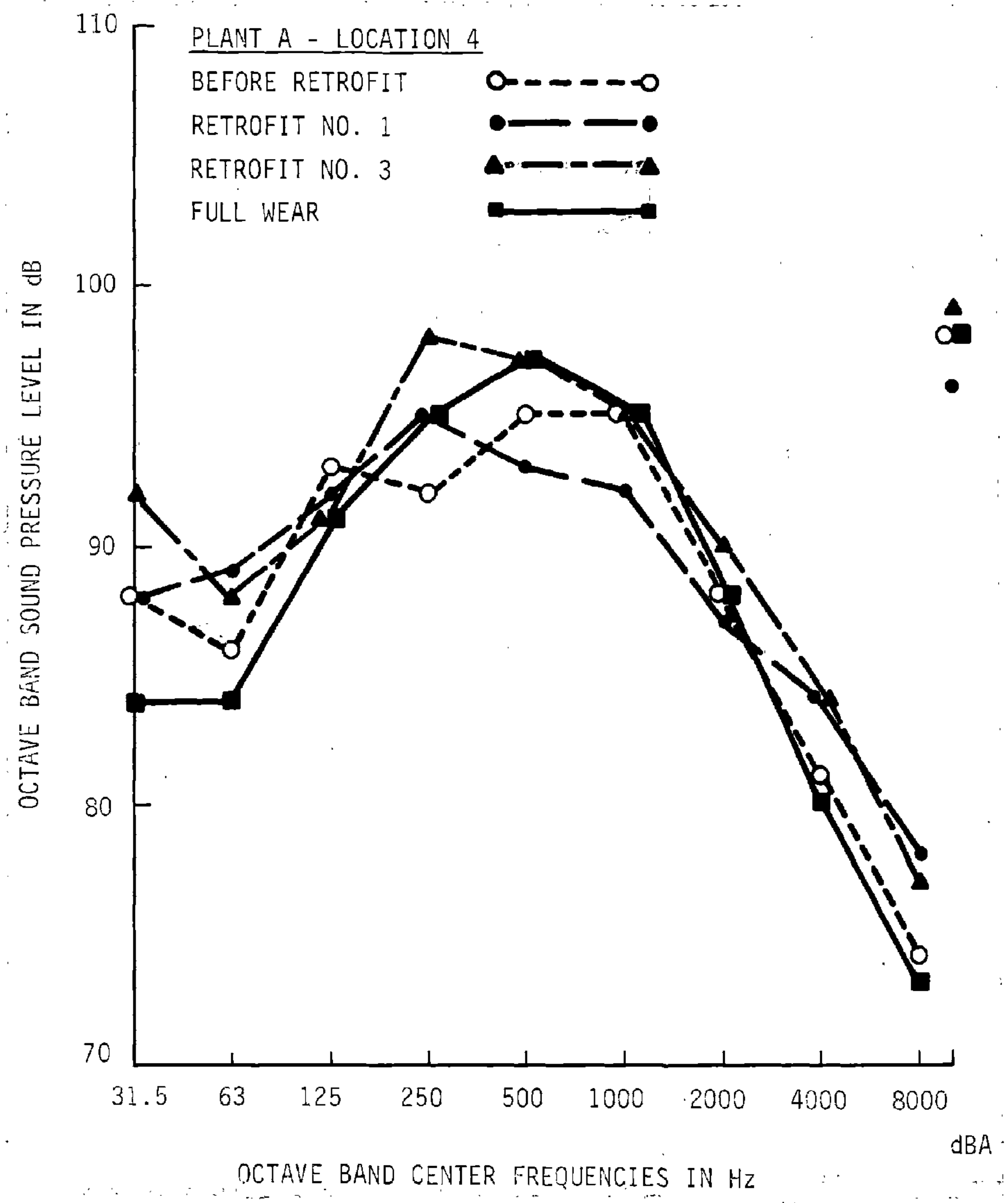


FIGURE C-5. - Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

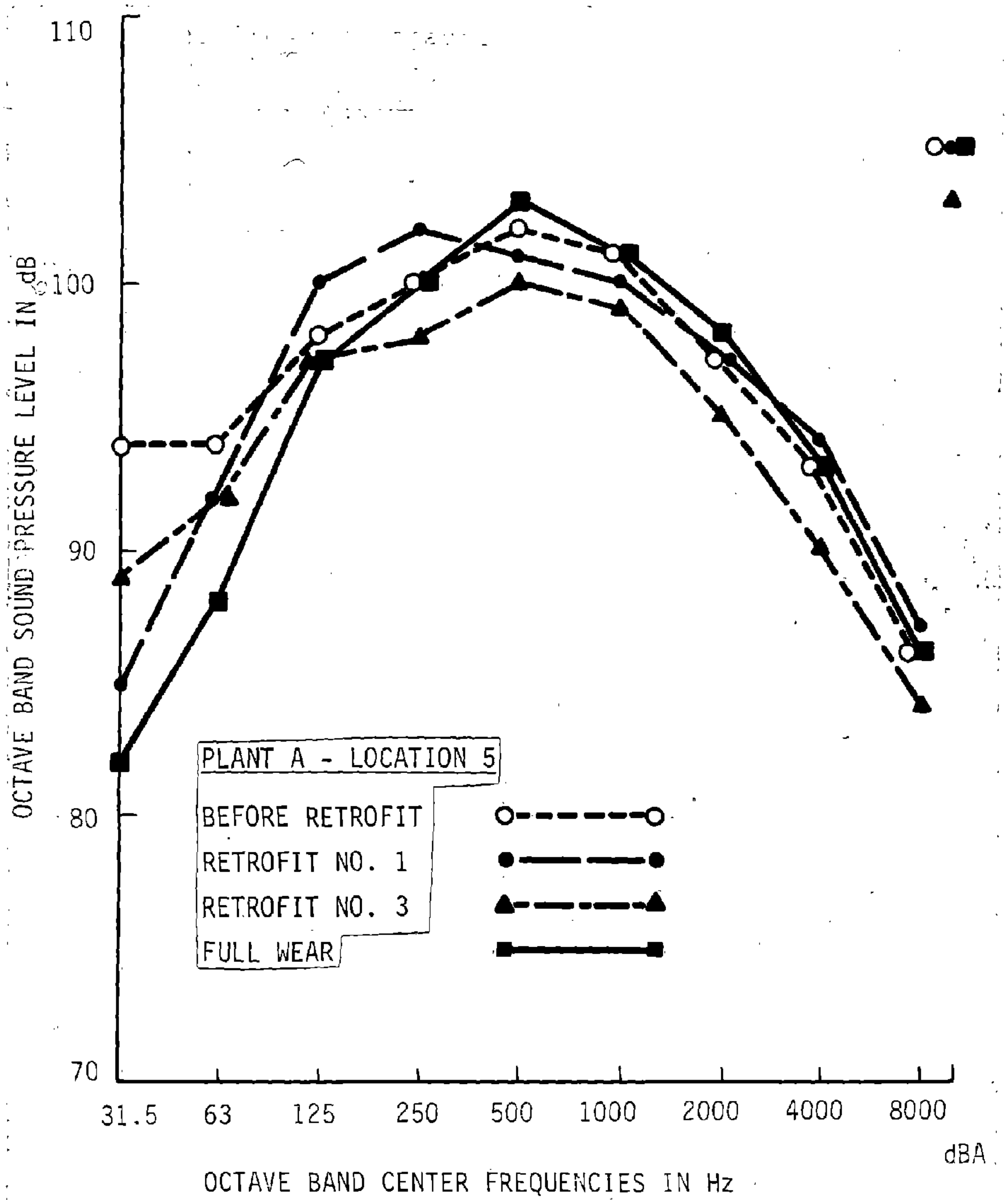


FIGURE C-6. Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

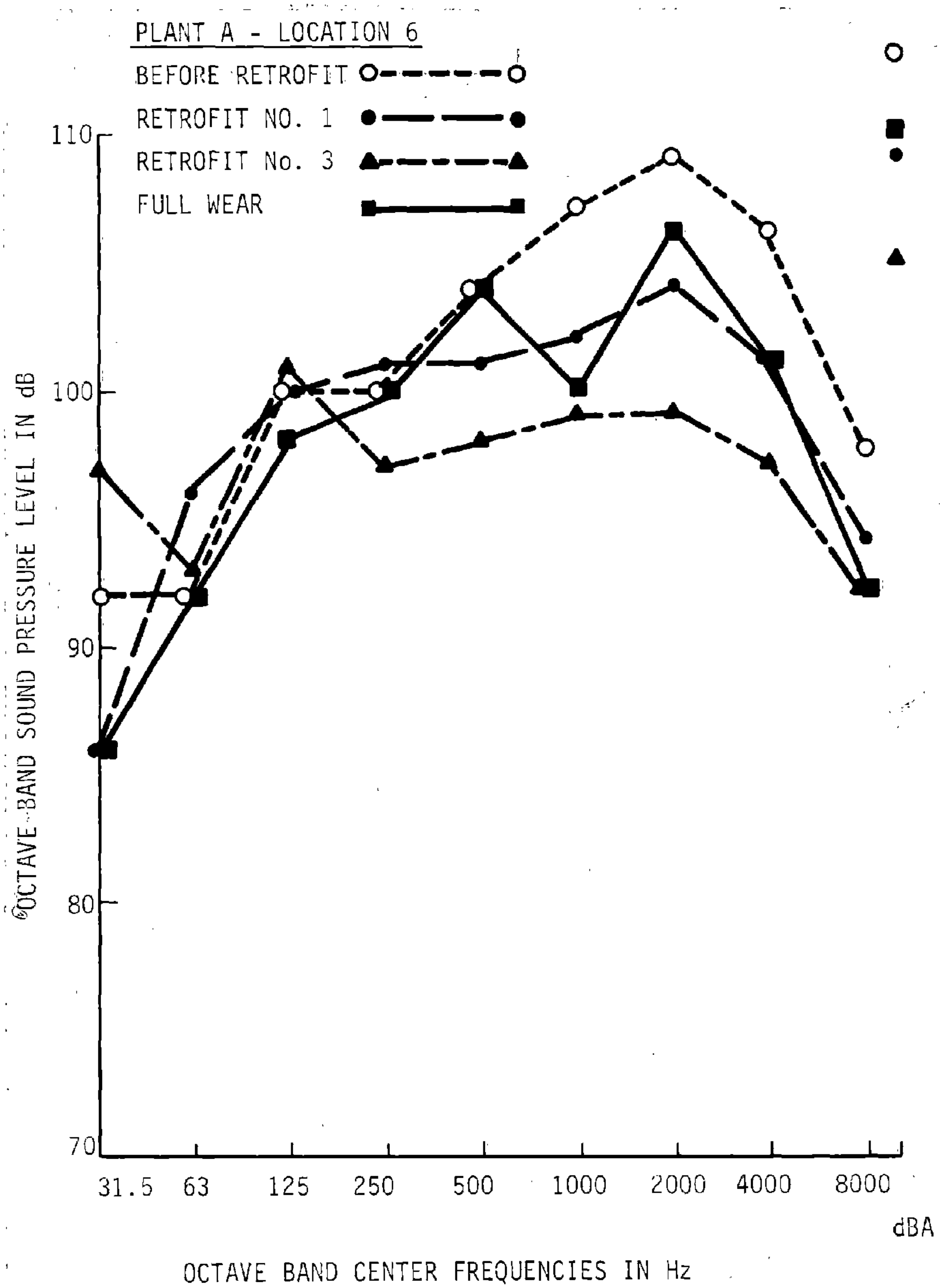


FIGURE C-7. Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

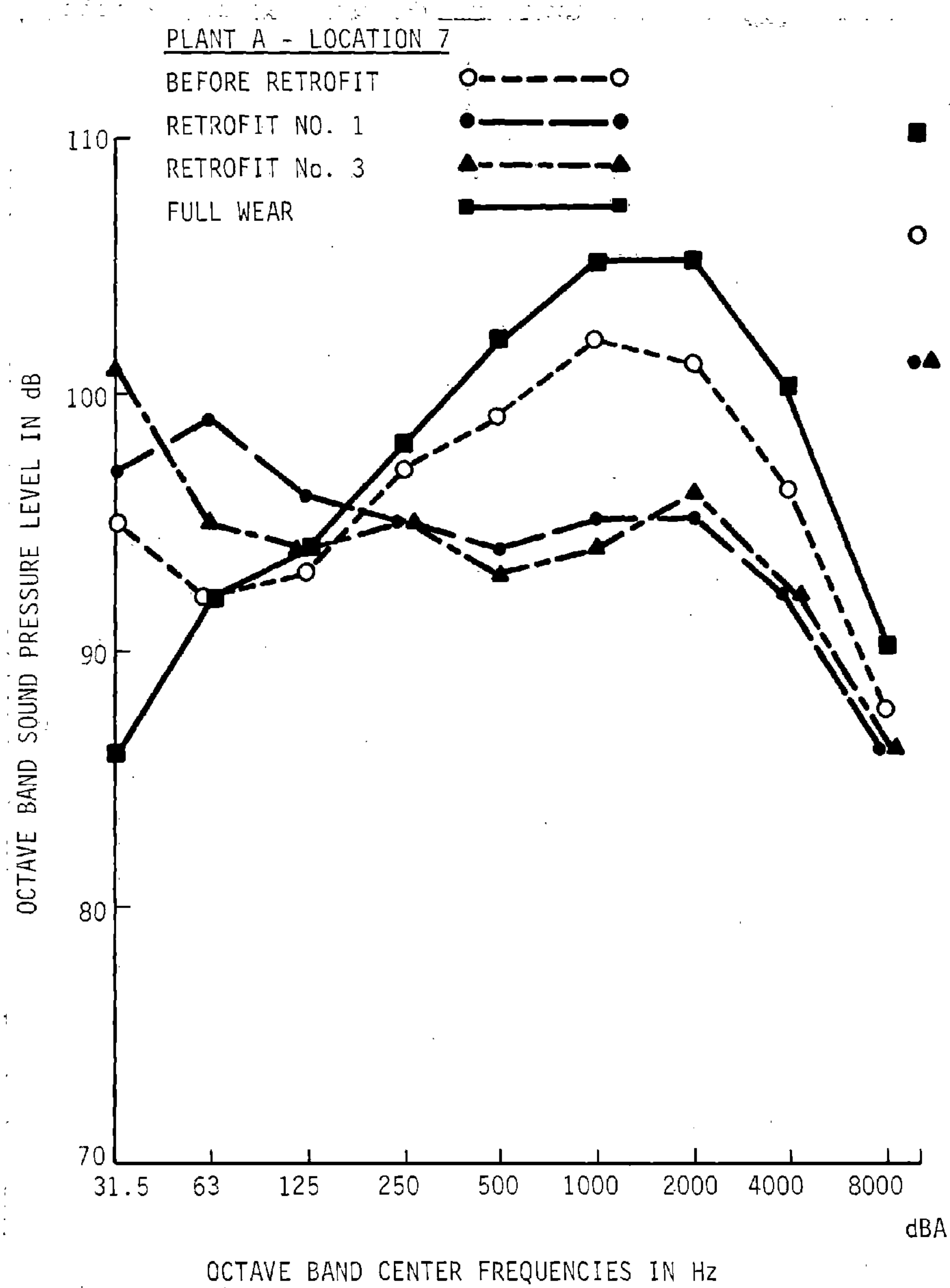


FIGURE C-8. - Sound pressure levels before and after treatment.

Proofer

Typist

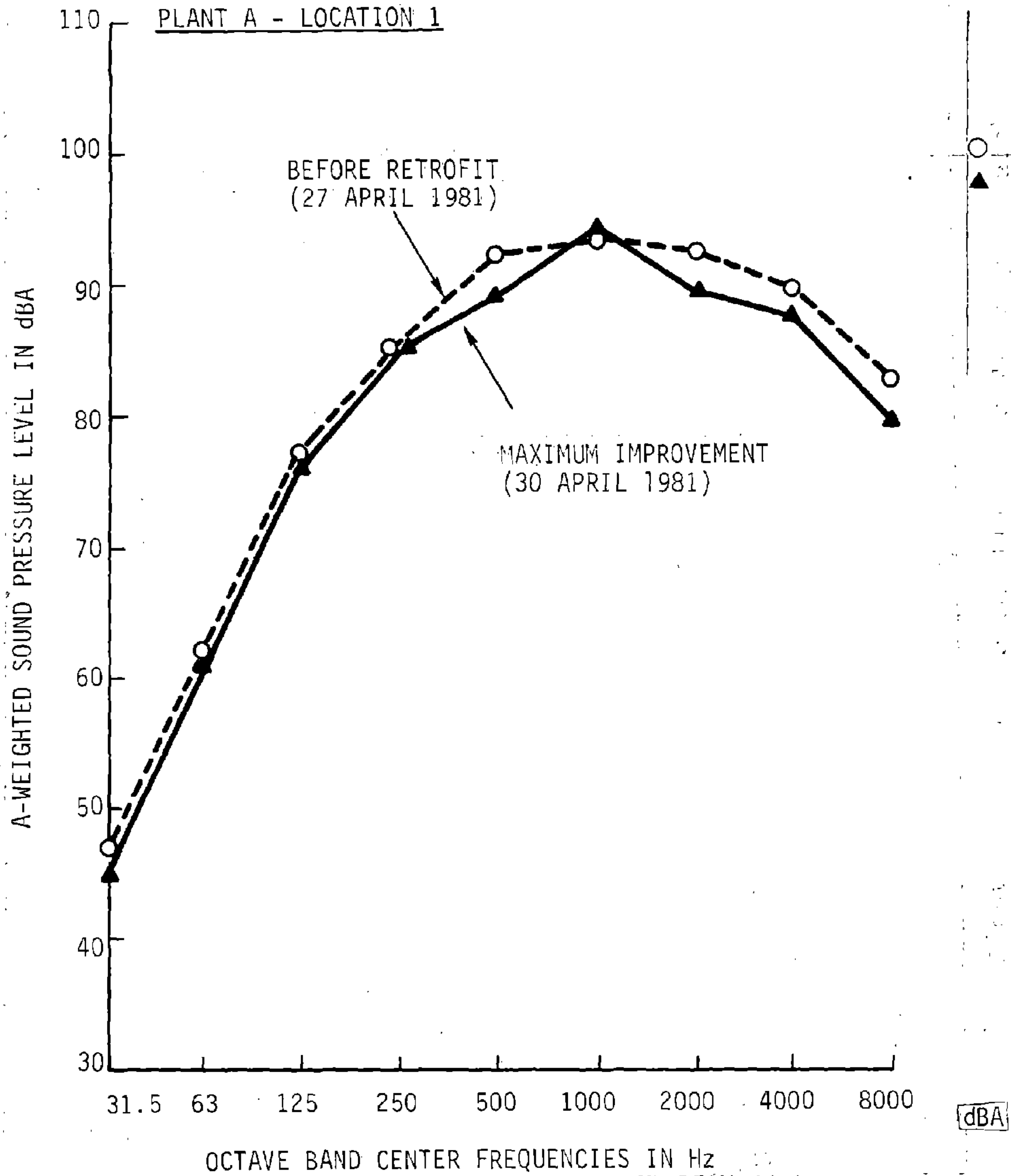


FIGURE C-9. - A-weighted sound levels before treatment and best improvement.

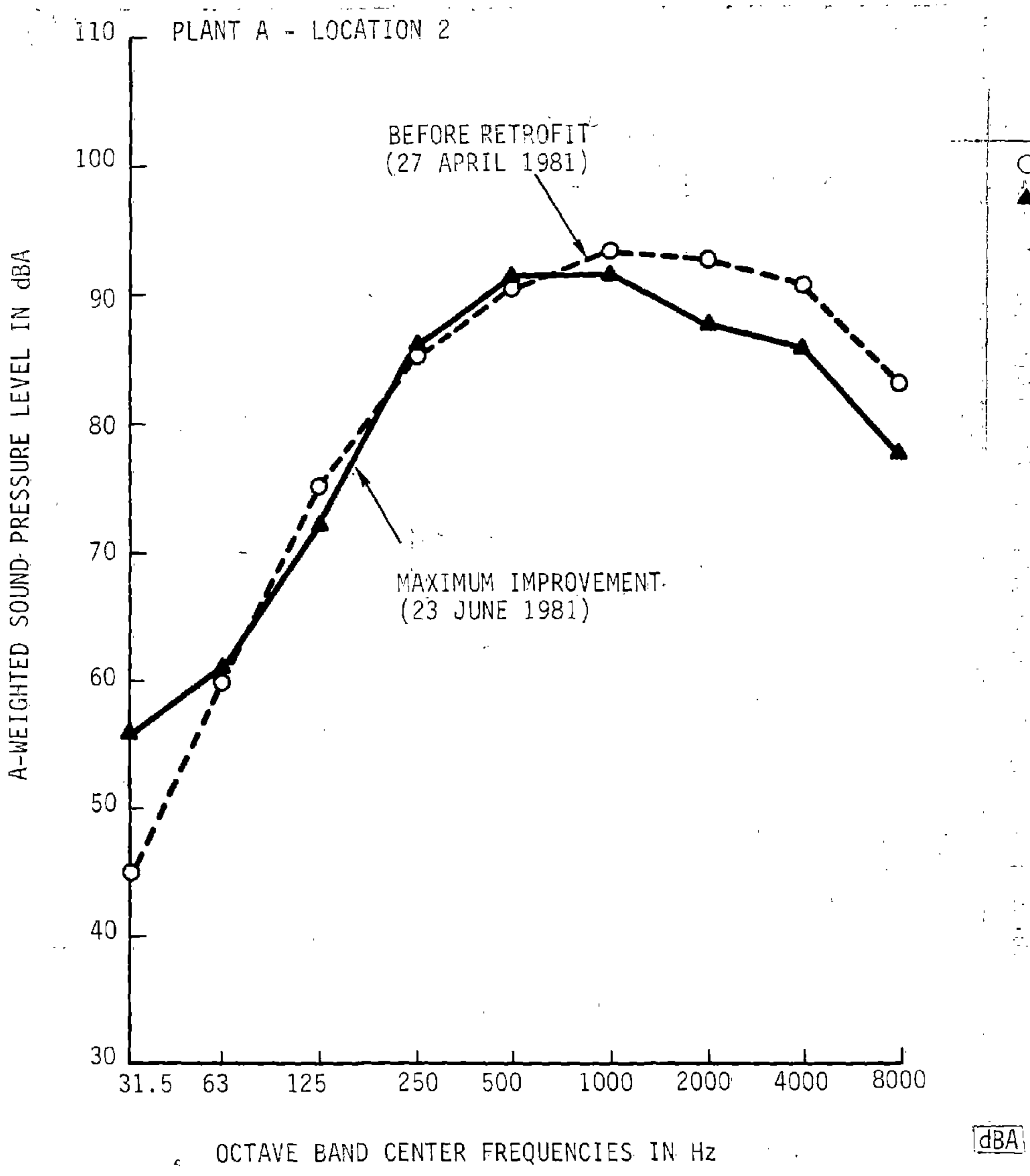


FIGURE C-10. - A-weighted sound levels before treatment and best improvement

Proofer ________ Typist ________

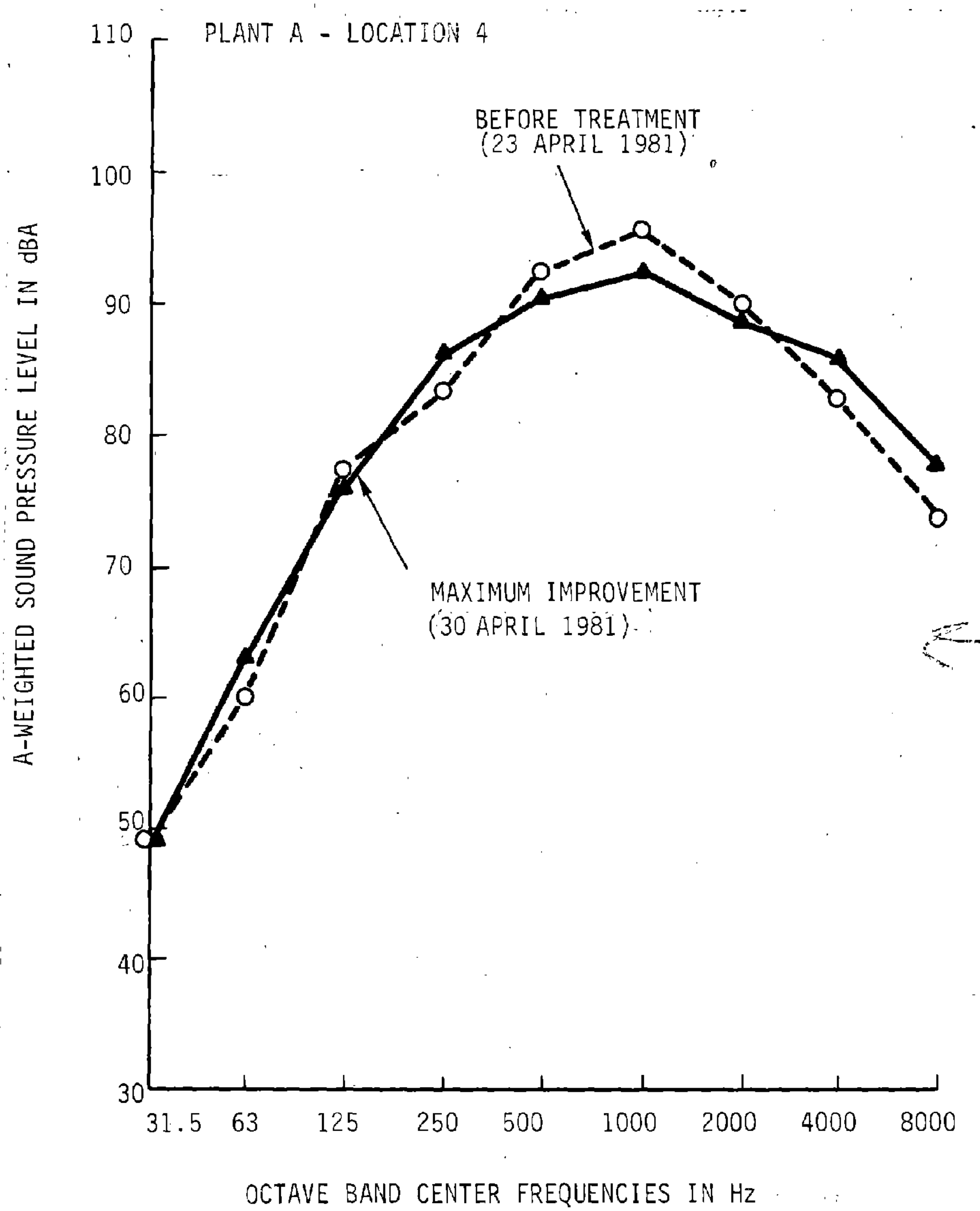


FIGURE C-11. - A-weighted sound levels before treatment and best improvement.

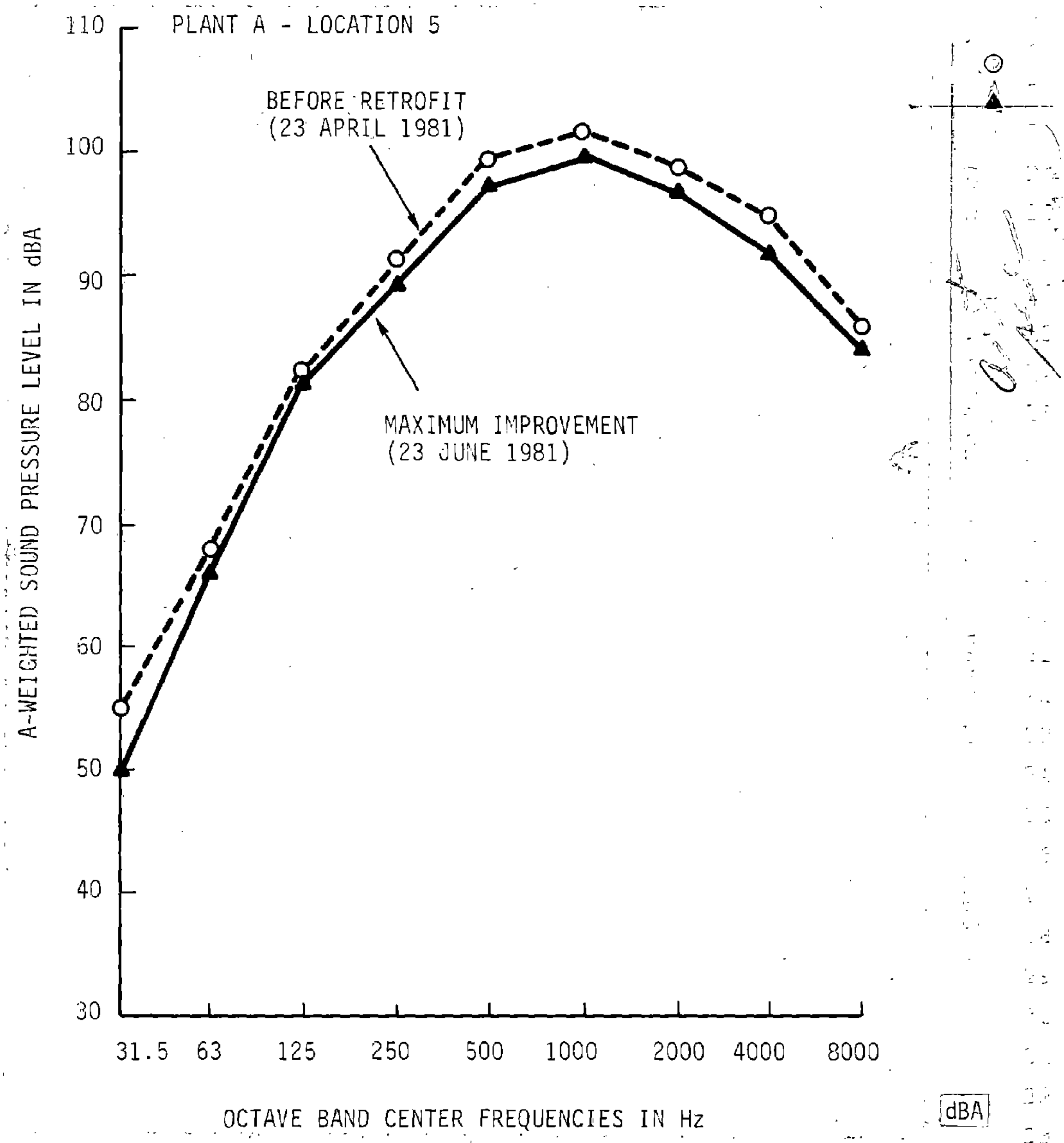


FIGURE C-12. - A-weighted sound levels before treatment and best improvement.

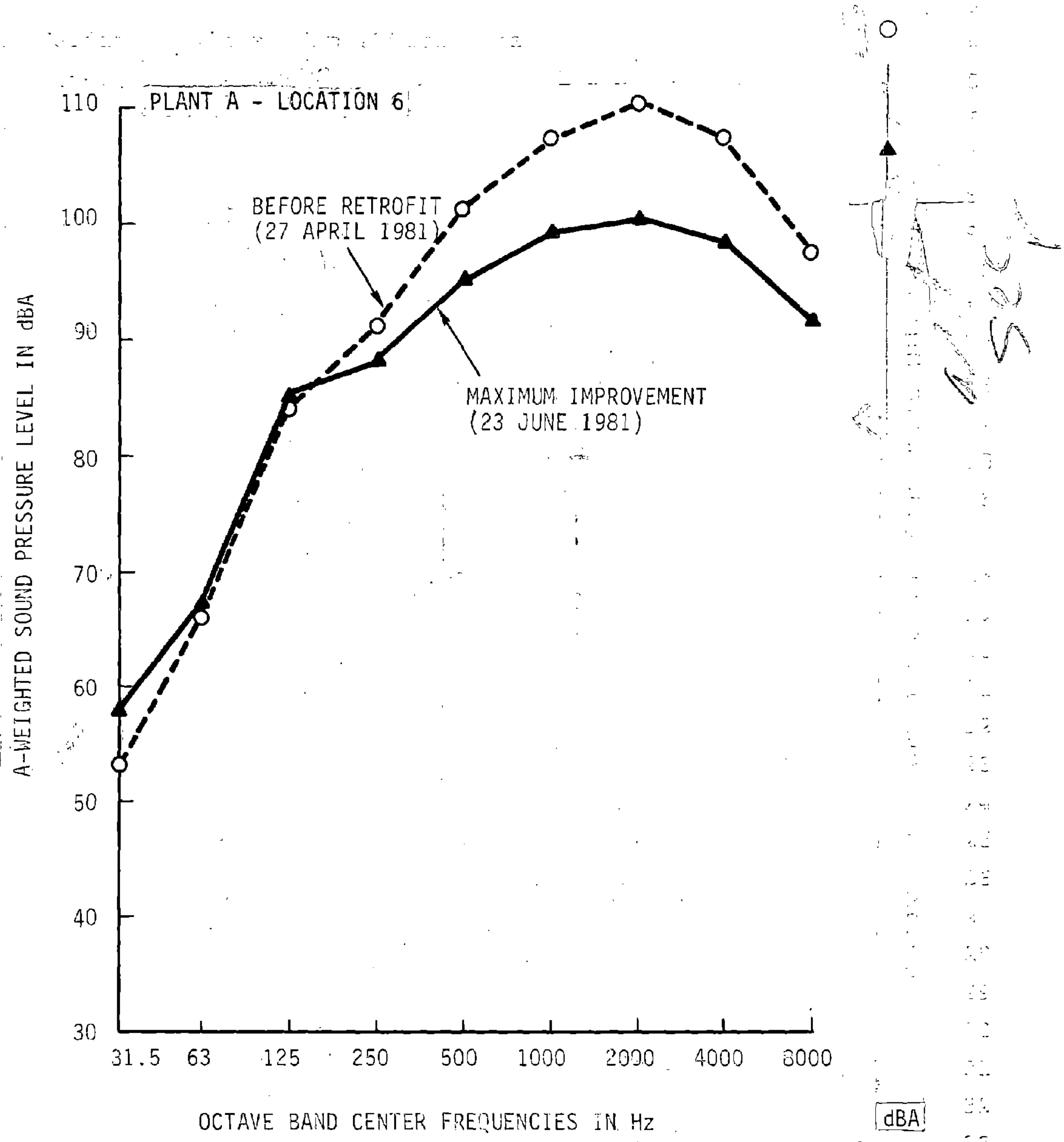


FIGURE C-13. - A-weighted sound levels before treatment and best improvement.

Proofer ______________ Typist ______________

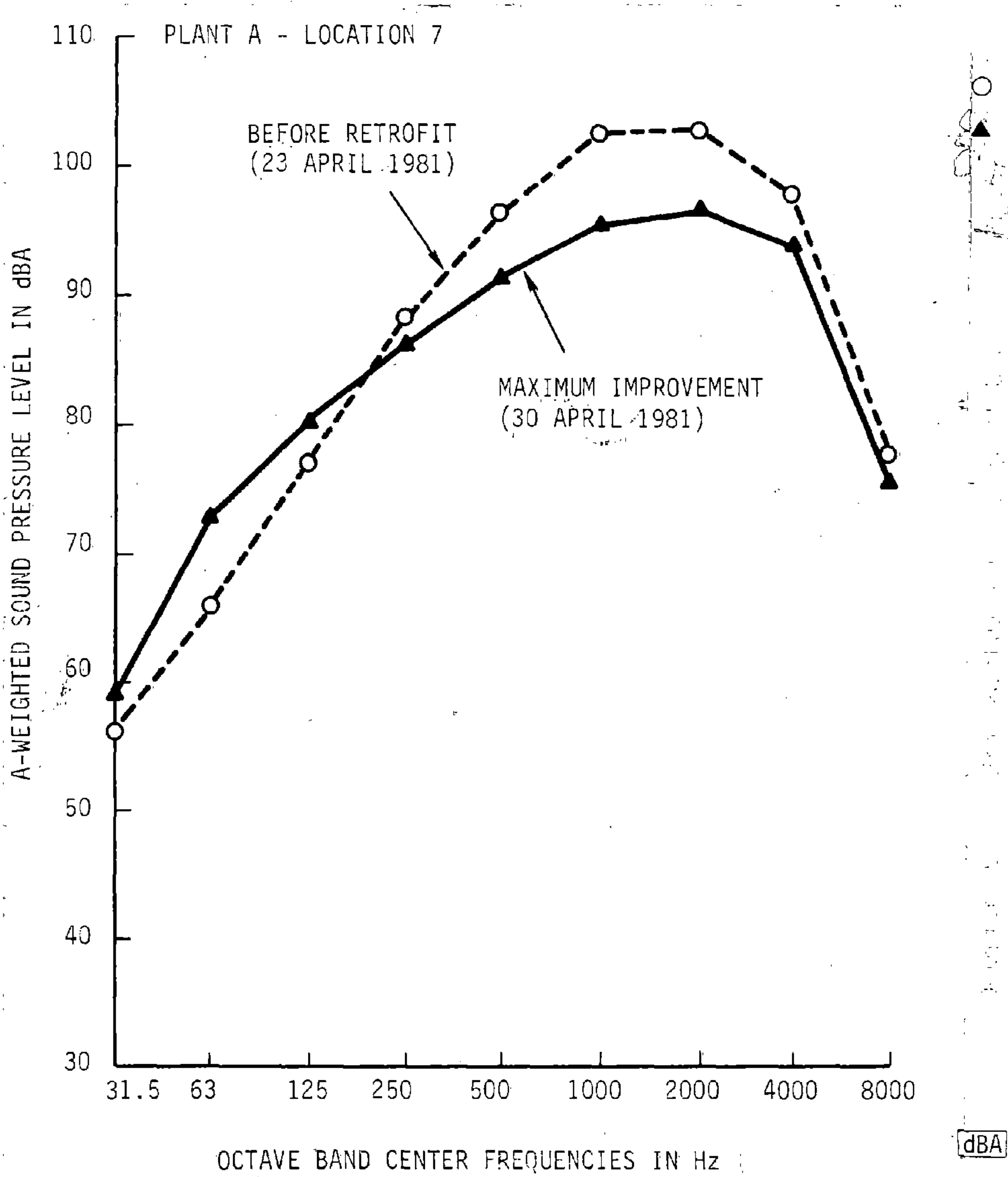
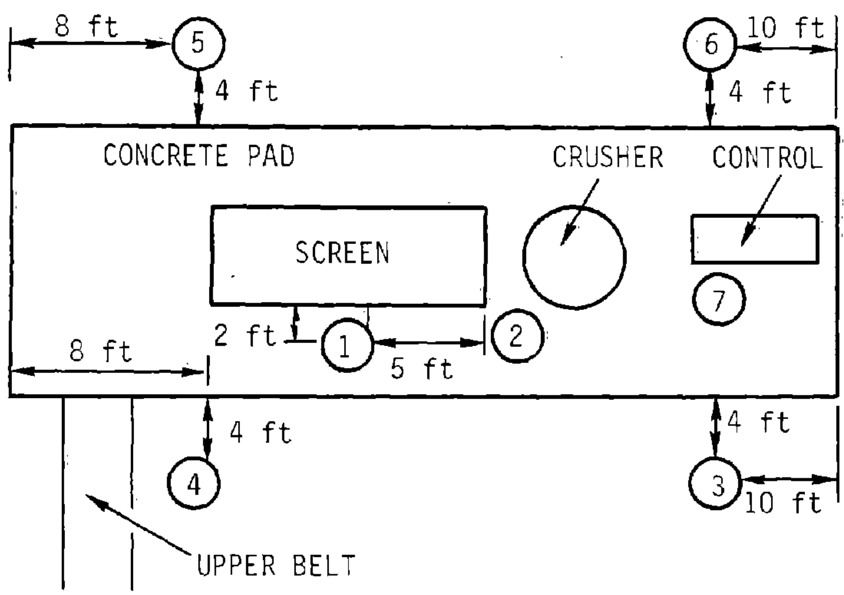


FIGURE C-14. - A-weighted sound levels before treatment and best improvement.

Proofer ________ Typist ________

6/80



POSITION 1	= AT SCREEN SIDE PLATE, 2 ft FROM SCREEN DRIVE
POSITION 2	= ADJACENT CRUSHER FEED HOPPER
POSITIONS 3, 4, 5, 6	= GROUND LEVEL
POSITION 7	= HYDRAULIC CRUSHER SETTING CONSOLE

FIGURE C-15. Plant B measurement locations.

Proofer ____________ Typist ____________

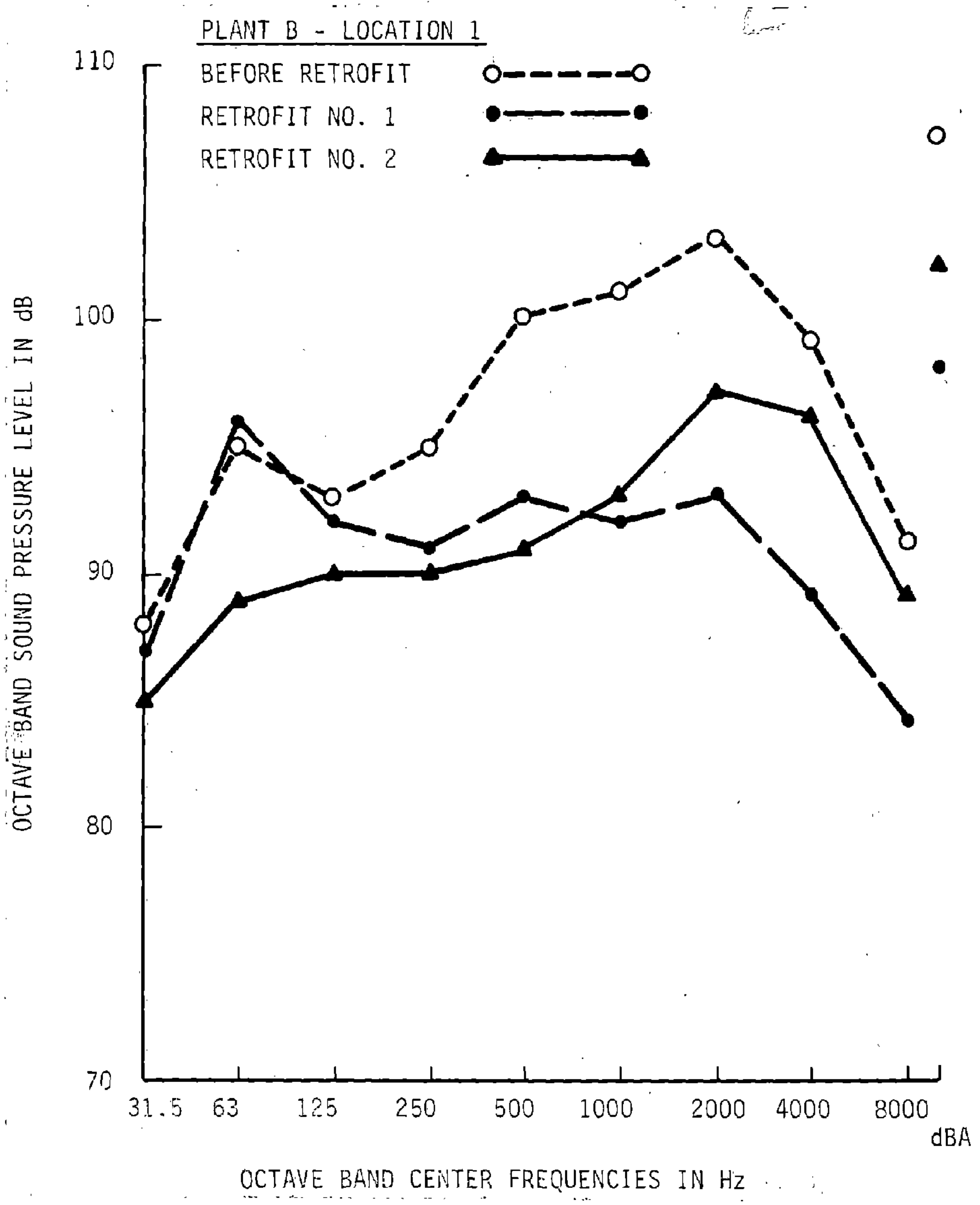


FIGURE C-16. - Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

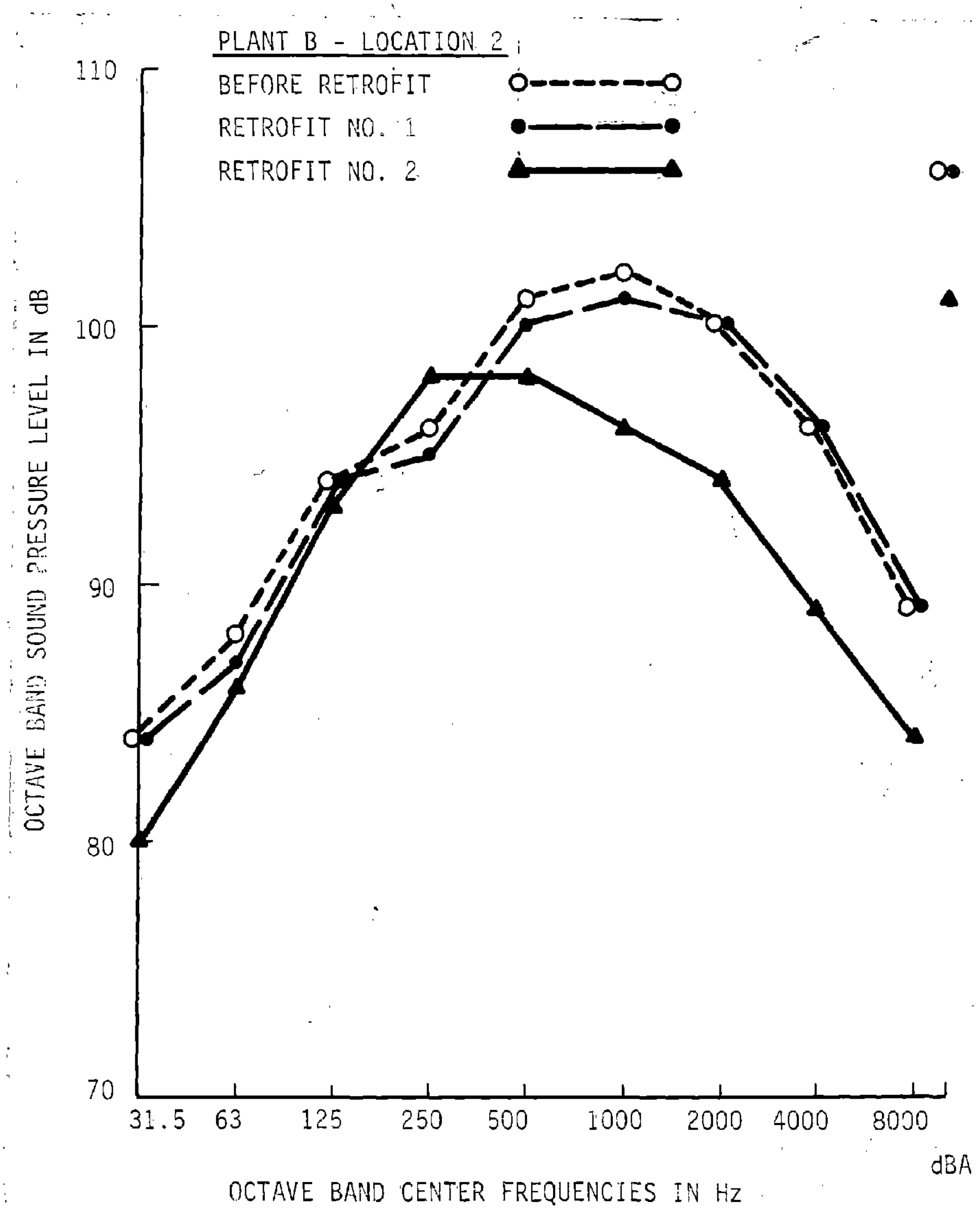


FIGURE C-17. - Sound pressure levels before and after treatment.

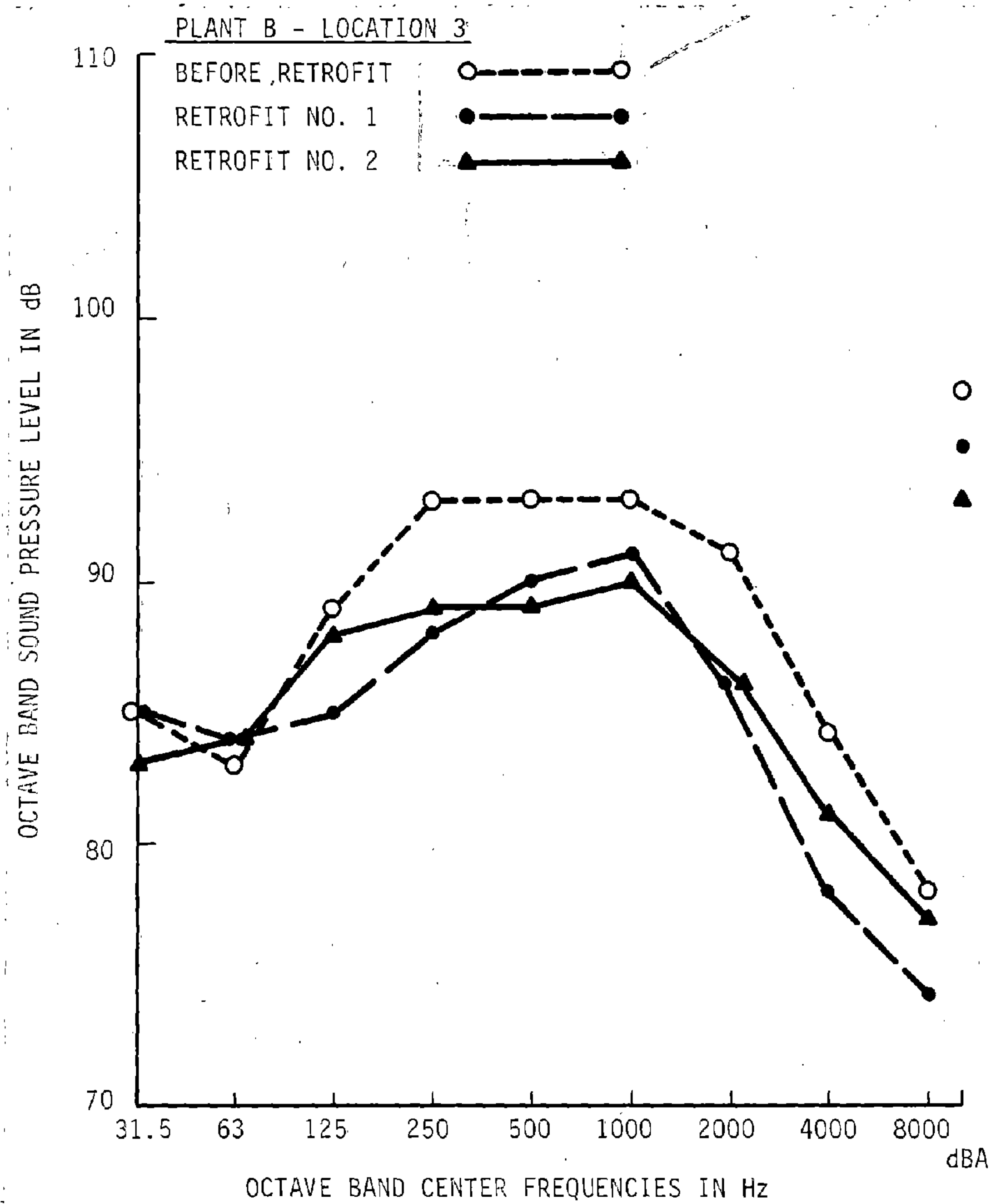


FIGURE C-18. - Sound pressure levels before and after treatment.

Proofer ______________ Typist ______________

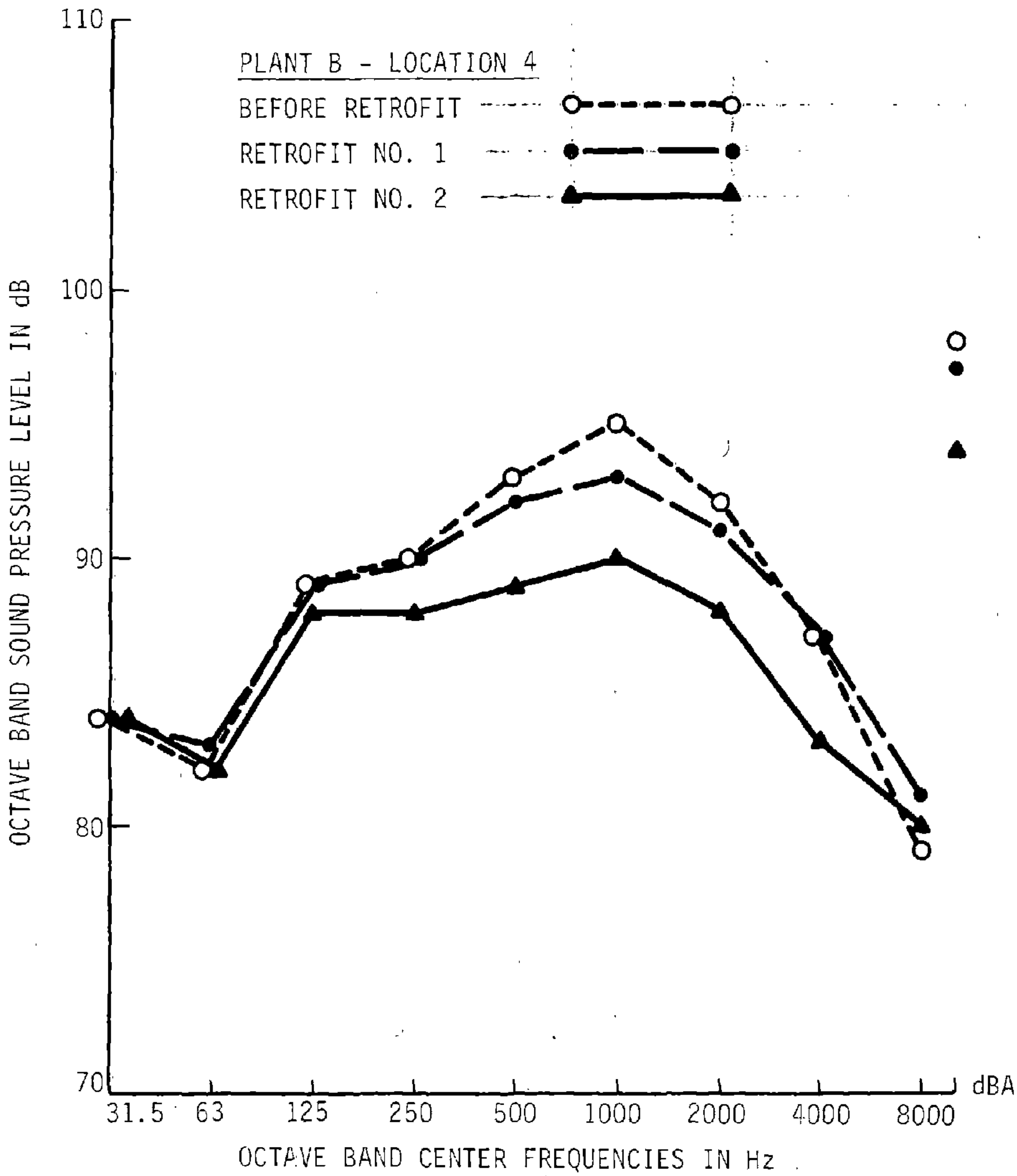


FIGURE C-19. - Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

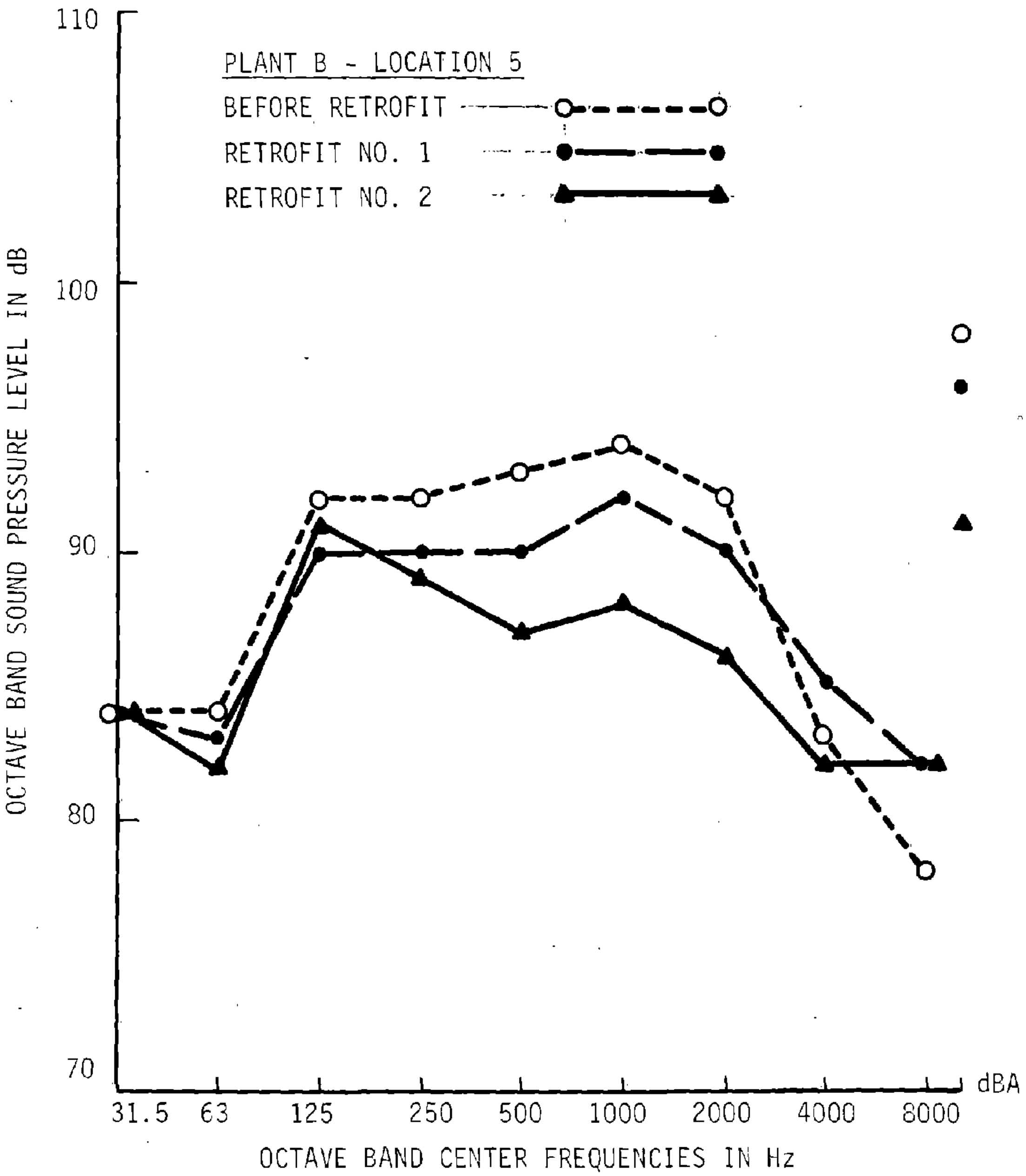


FIGURE C-20.- Sound pressure levels before and after treatment.

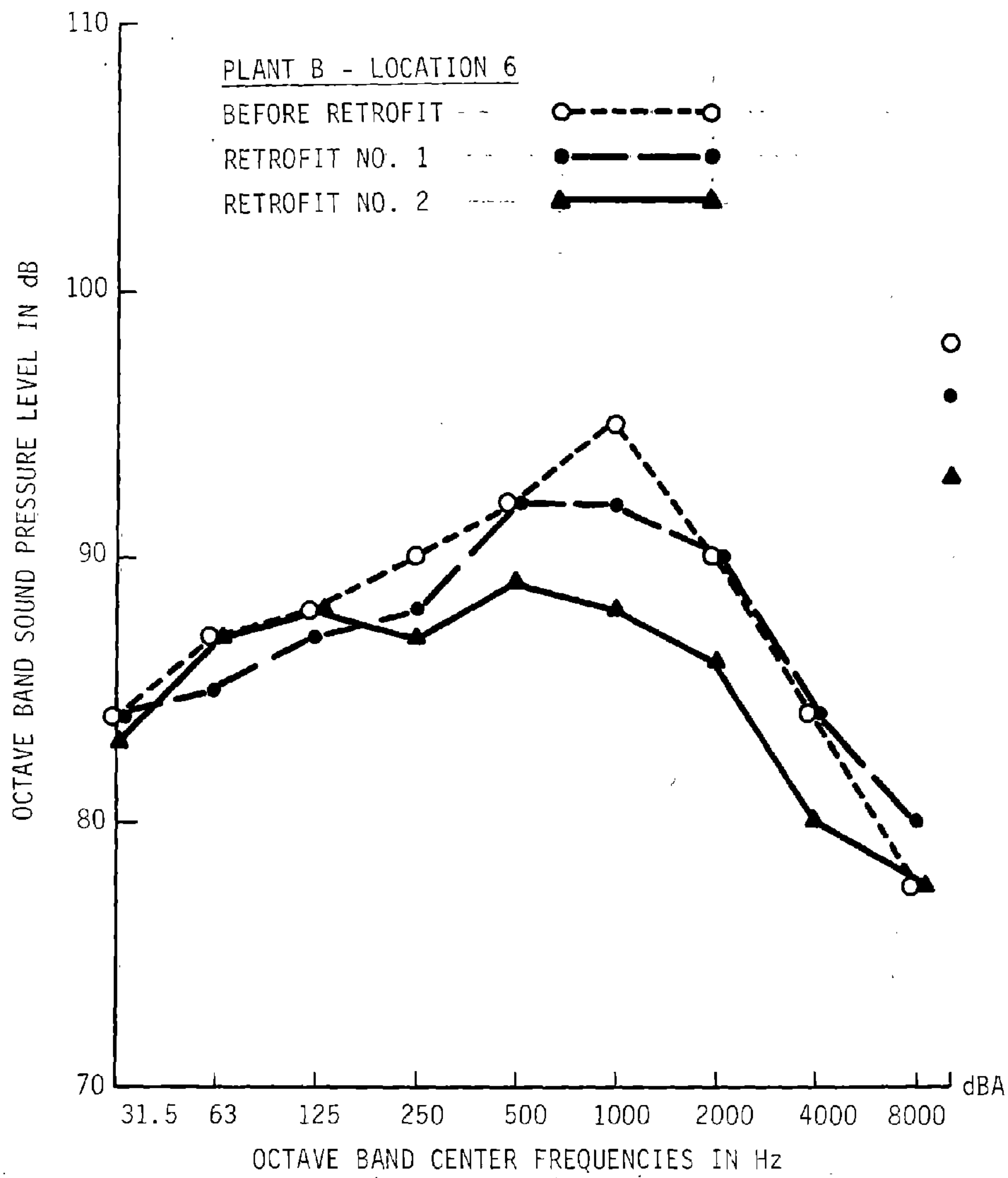


FIGURE C-21. - Sound pressure levels before and after treatment.

Proofer ____________ Typist ____________

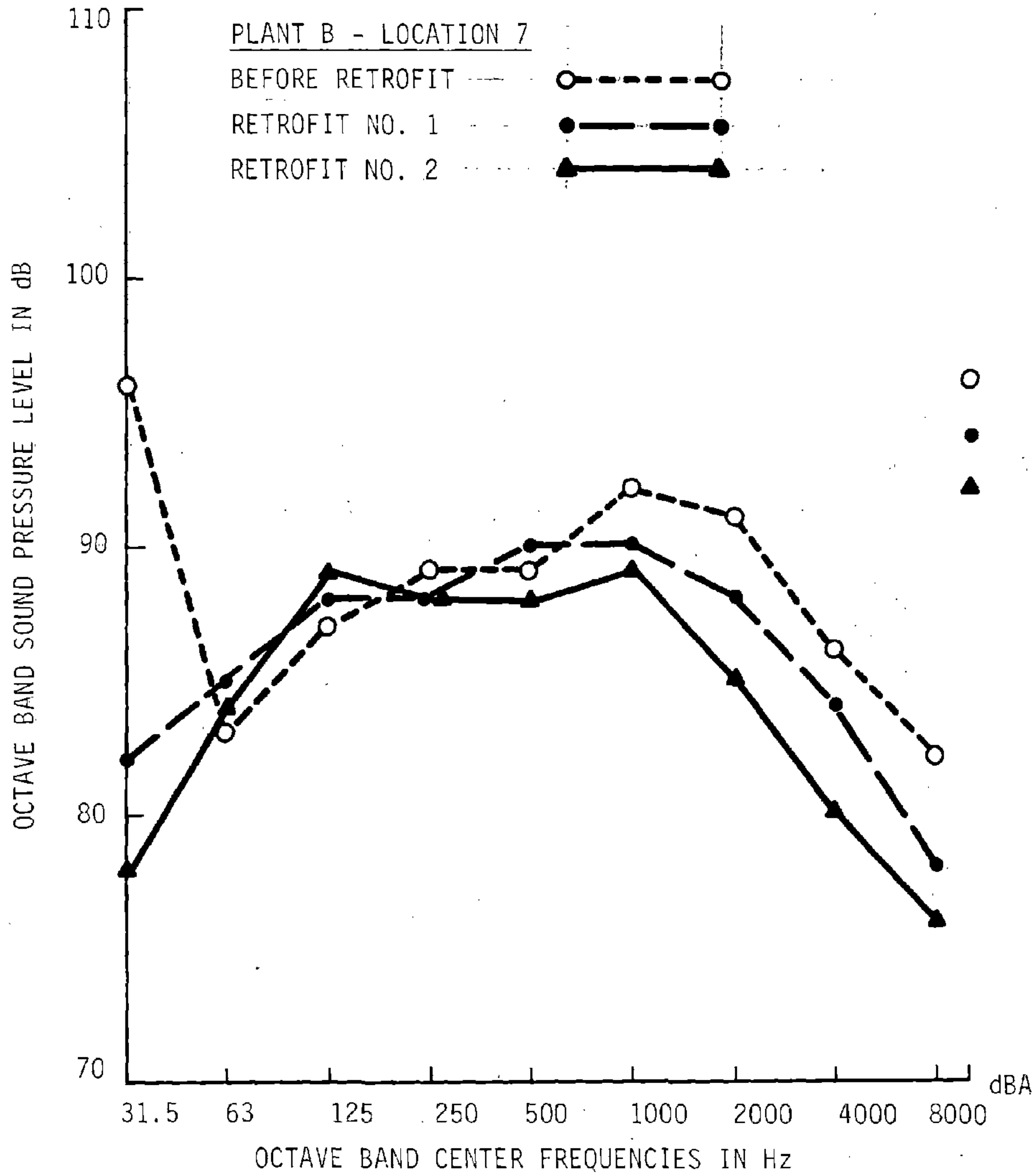


FIGURE C-22. - Sound pressure levels before and after treatment.

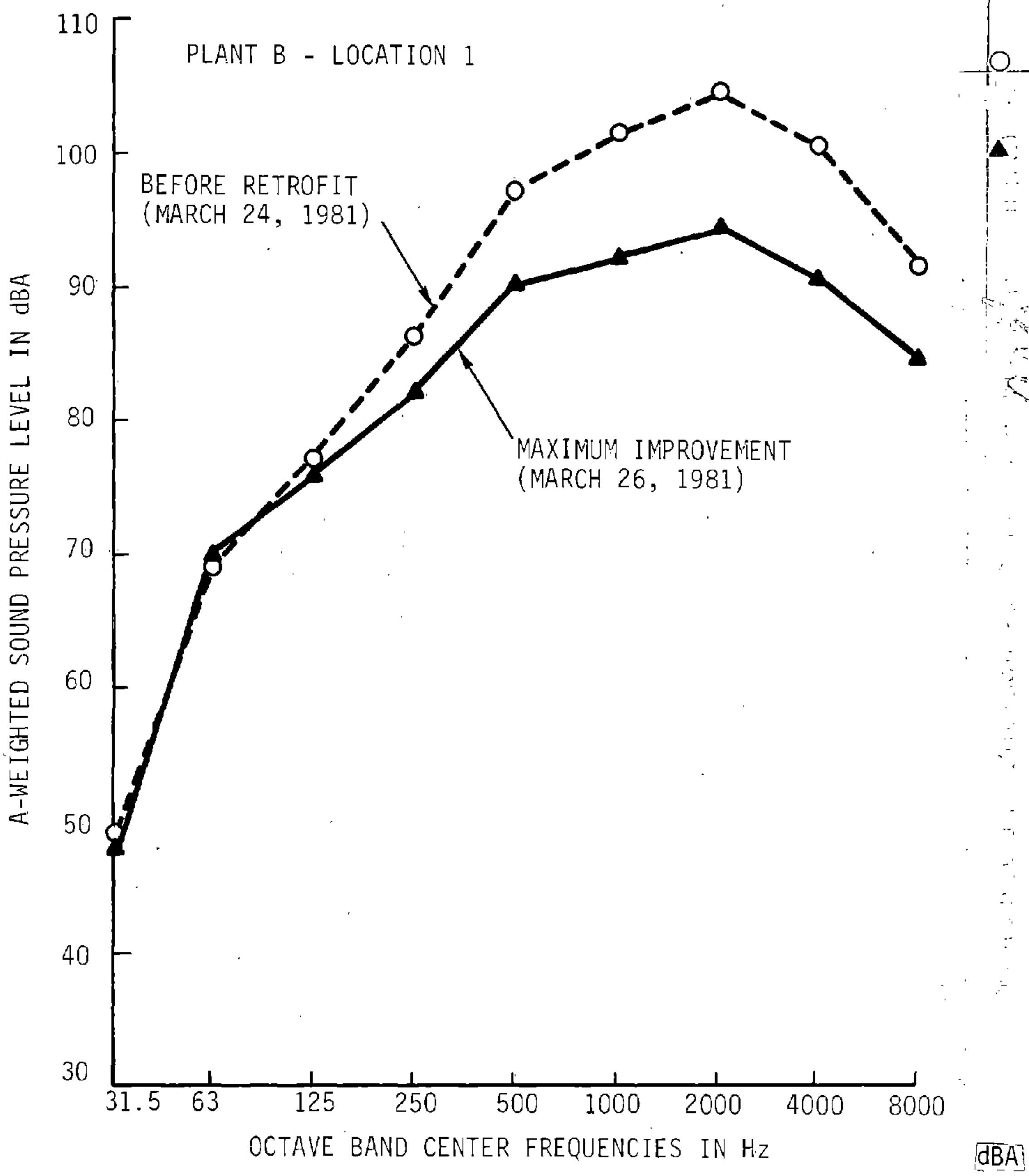


FIGURE C-23. - A-weighted sound levels before treatment and best improvement.

Proofer ____________ Typist ____________

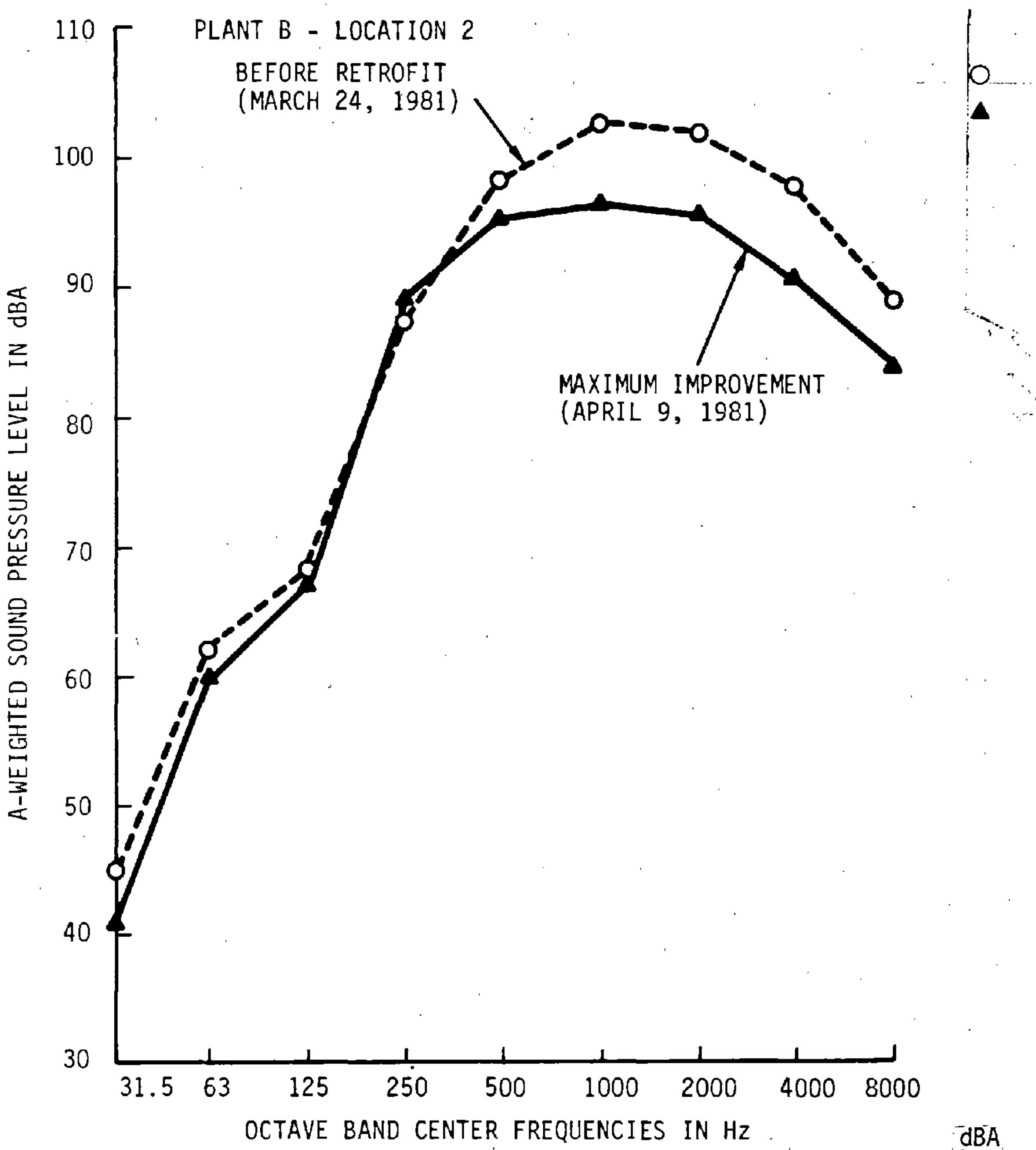


FIGURE C-24. - A-weighted sound levels before treatment and best improvement.