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Noise Abatement of Pneumatic Rock Drill

UNITED STATES DEPARTMENT OF THE INTERIOR

Bureau of Mines

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NOISE ABATEMENT OF PNEUMATIC ROCK DRILL

by

C. R. Summers and J. N. Murphy

ERRATA

On page 14 under DISCUSSION OF RESULTS, the fourth line should read figure 10 instead of figure 11.

On page 42, the line should read as follows: ...the top (fig. B-21).

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Noise Abatement of Pneumatic Rock Drill

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UNITED STATES DEPARTMENT OF THE INTERIOR
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NOISE ABATEMENT OF PNEUMATIC ROCK DRILL

by

C. R. Summers [1] and J. N. Murphy [2]

ABSTRACT

In response to the Coal Mine Health and Safety Act of 1969, mandatory noise standards have been developed that specify time-noise limits of mine personnel exposure. Most affected by elevated noise levels is the pneumatic roof bolter operator, both in terms of levels near or in excess of 115 dbA and in terms of length of exposure. Therefore, the principal emphasis of this Bureau of Mines report is on pneumatic drill noise control.

It is not the intent of this report to suggest any drill redesign; instead, methods are suggested to reduce the noise level by complementing existing machines. An integral muffler system and a separate muffler system were tested in an attempt to lower pneumatic drill noise levels. Pneumatic drills, when new, operate at about 115 dbA when drilling in sandstone. Using the drill muffler systems, it was possible to decrease the noise level of a 115-dbA stope drill to approximately 100 dbA.

INTRODUCTION

In response to the Coal Mine Health and Safety Act of 1969[3] (hereafter referred to as the Act), mandatory noise standards have been developed that specify time-noise limits of personnel exposure. In meeting this noise exposure criteria, multiple noise sources, varying levels, and exposure times are encountered.

The Mandatory Health Standards of the regulations prescribe maximum noise levels as shown in table 1; the data in the table is shown graphically in figure 1. Note that the exposure criterion is nonlinear, hence compounding computation of exposure with the varying sources described previously. An additional requirement of the noise exposure requirements is that the miner shall never be exposed to sound levels greater than 115 dbA.

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[1] Research physicist.
[2] Supervisory electrical research engineer.
[3] Public Law 91-173, December 1969.

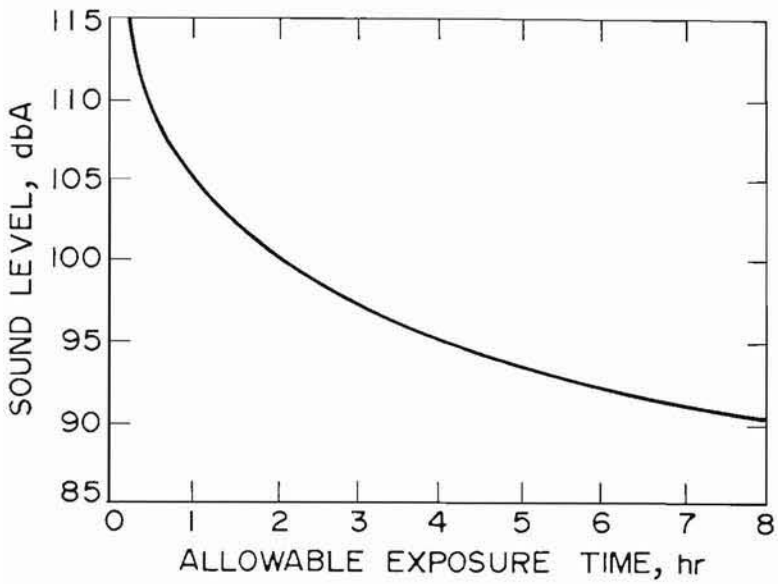

FIGURE 1. - Permissible noise levels as a function of time.

TABLE 1. - Permissible noise exposures

Duration per day, hr	Noise level, dbA
8............	90
6............	92
4............	95
3............	97
2............	100
1-1/2........	102
1............	105
3/4........	107
1/2........	110
1/4 or less	115

The severity of noise exposure and levels in underground coal mines for various work assignements is given by a 21-mine survey conducted by Lamonica, Mundell, and Muldoon[4] as shown in table 2. It is apparent that the pneumatic roof bolter is by far the most serious problem, both in terms of levels near or in excess of 115 dbA and in terms of exposure. Research is underway concerning the other problem areas, but principal emphasis here will be devoted to research on drill noise control.

TABLE 2. - Calculated noise exposures and sound levels for underground coal mine occupations based on Walsh-Healey Public Contracts Act

Occupation	Number sampled	Walsh-Healey Public Contracts Act safety and health standards noise exposure criteria[1]		Sound level, dbA	
		Mean	Range	Mean	Range
Pneumatic bolter operator	9	7.64	3.94	112	104-118
Continuous miner operator	17	1.15	.11-2.64	97	89-107
Loading machine operator.	8	1.13	.43-1.93	99	90-108
Rotary bolter operator...	12	.70	.50-1.51	95	85-106
Cutting machine operator.	5	.51	.27- .72	94	85-103
Coal drill operator......	3	.41	.2 - .75	94	80-104
Shuttle car operator.....	8	.28	.09- .72	93	90- 98

[1]Criterion: Actual exposure divided by allowable exposure shall not exceed unity.

[4]Lamonica, J. A., R. L. Mundell, and T. L. Muldoon. Noise in Underground Coal Mines. BuMines RI 7550, 1971, 11 pp.

Previous investigators[5] have identified the general noise sources of a particular drill; the Bureau work was directed toward the 75-lb class of pneumatic drill with feed leg used for roof bolting operations in some underground coal mines, such as that shown in figure 2. These drills, when new, operate at about 115 dbA when drilling in sandstone; with noise abatement modifications, the levels have been reduced to about 100 dbA without significant reduction in drilling performance. Further reductions can be achieved with deterioration of drill performance. The ultimate level in the field is dependent on the reverberant conditions in which the drill is operated; the extent of maintenance of the noise control devices and on the extent of worn parts such as chuck liners, piston walls, and cylinder walls.

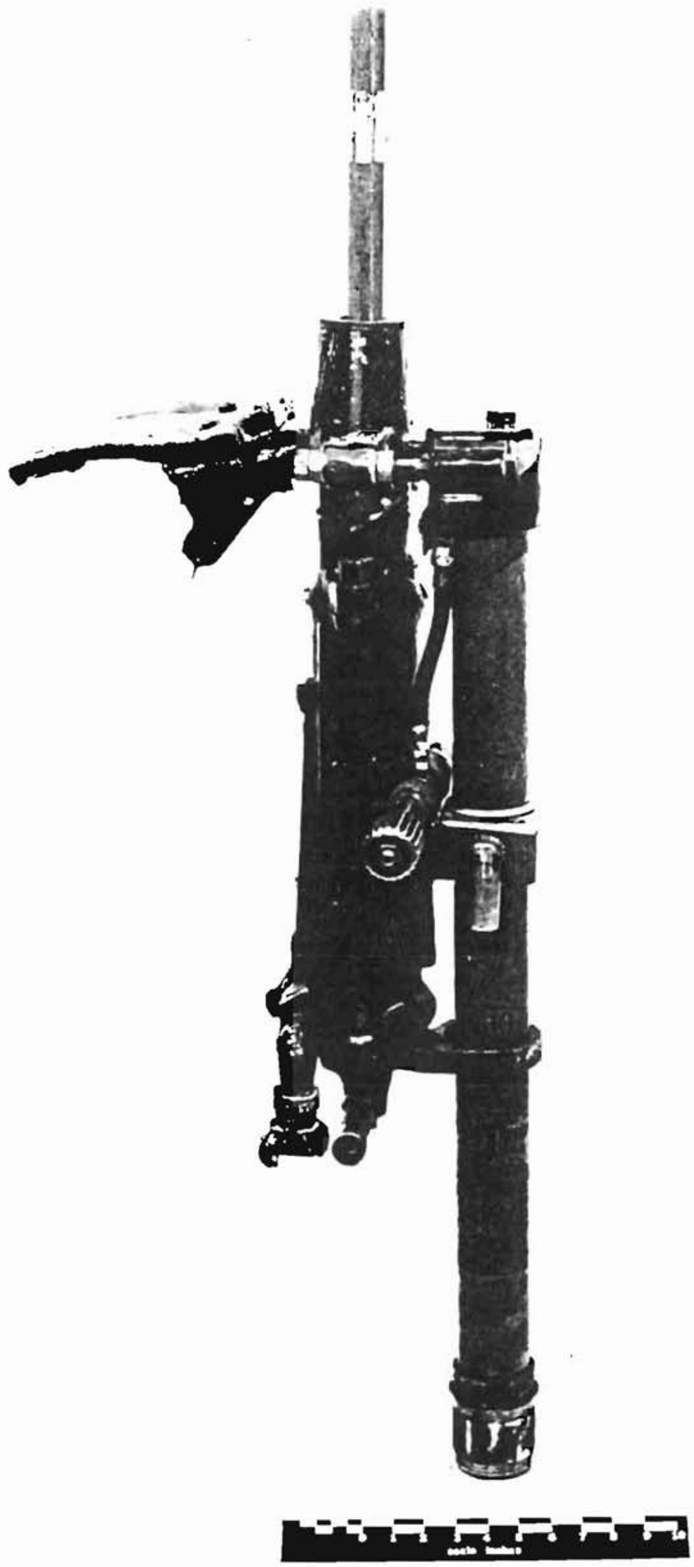

FIGURE 2. - Unmodified Ingersoll-Rand stoper drill.

The principal noise sources in order of importance to reduce the overall drill noise level are as follows:

1. Exhaust noise.--Pulse of high-pressure air from the reciprocating piston creating high-intensity

[5]Biers, J. L. A Study of Noise Sources in Pneumatic Rock Drills. J. Sound Vib., v. 3, No. 2, 1966, pp. 166-194.

noise bursts. The exhaust port also creates an outlet for internal mechanical noises.

2. Impact noise.--Mechanical impact of the piston upon the rod end within the drill body.

3. Drill rod noise.--Transverse vibrations of the drill rod upon being struck by the piston.

4. Bit noise.--Collision of the rod end or bit with the rock within the hole, again perhaps causing vibrations of the rod.

It is often stated that about 90 percent of the drill noise is caused by the high-energy release of exhaust air. This statement may lead to the thought that if the exhaust noise were eliminated, a sound level meter would show 90 percent or 20 dbA less, since the meter is measuring sound pressure rather than energy. The decibels in energy is equal to 10 log energy/reference energy, whereas the decibels the meter registers is 20 log pressure/reference pressure. Therefore, a 90-percent reduction in energy would show only a 10-db reduction on a sound level meter. The comparison of noise pressure level with noise energy level is shown in table 3.

TABLE 3. - Decibel reduction of noise pressure level compared with change in noise energy level

Reduction, db	Energy reduction, pct	Pressure reduction, pct
5	68.0	43.7
10	90.0	68.4
15	97.0	82.2
20	99.0	90.0
25	99.7	94.4

Previous investigations have attempted to adapt mufflers to drills, but mufflers noticeably reducing noise levels generally suffered from (1) significant back pressure, which reduced drill performance, and/or (2) icing, due to moisture in the air line with the end result of a plugged exhaust port.

A good muffler is by no means the total answer to noise control of a pneumatic drill. In most cases, the mechanical noise and the drill steel noise are at as high a level as the exhaust noise. Thus, a muffler may reduce the total noise only 2 or 3 db.

Drill noise has a wide spectral distribution principally because of the multiple numbers of sources described previously. A typical distribution curve for an unabated drill is shown in figure 3 (solid line). The broken line shows the result of a good muffler when the drill steel noise was eliminated.

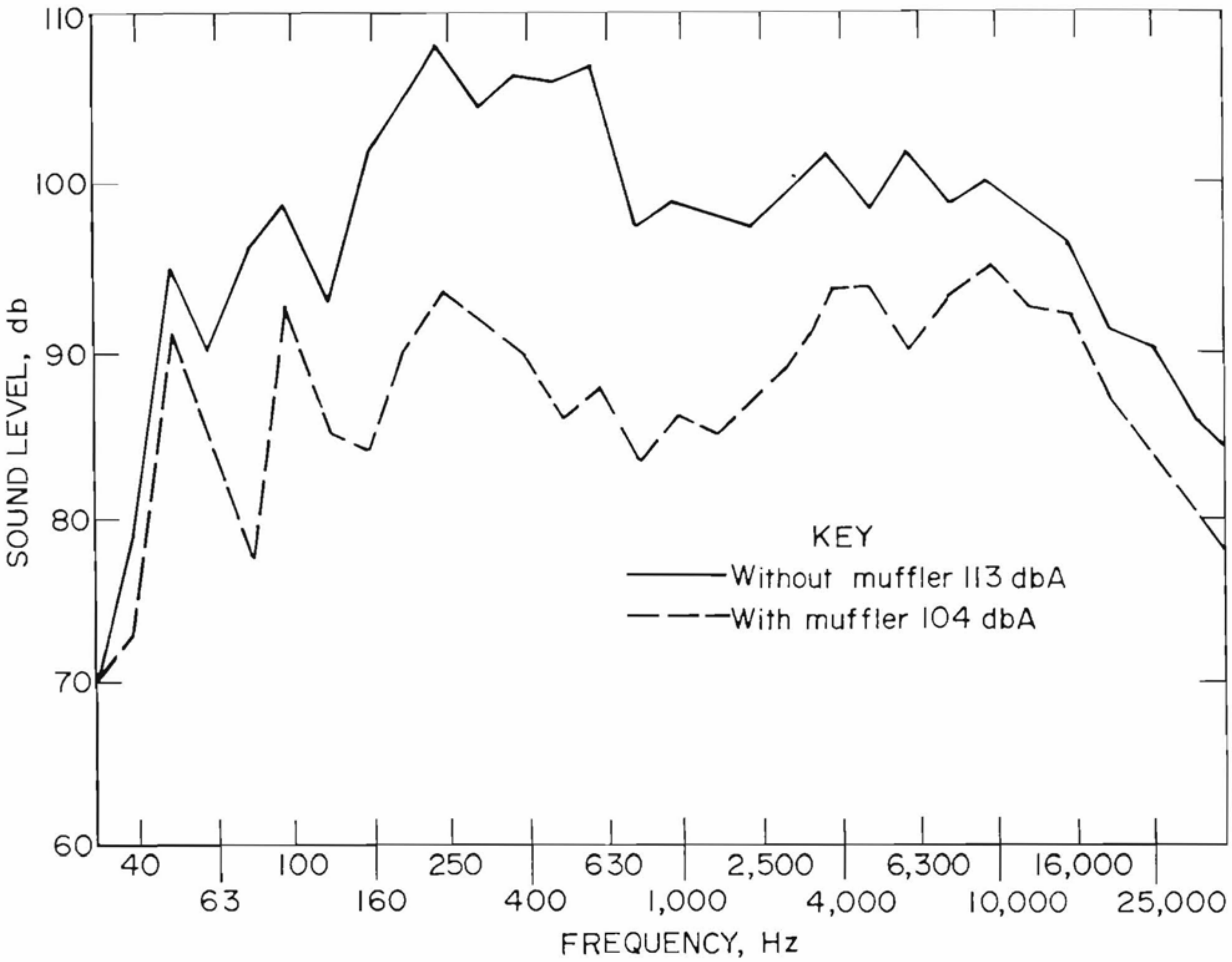

FIGURE 3. - Frequency distribution of sound pressure level of a pneumatic drill with and without muffler, drill steel noise eliminated.

The bit noise source has not as yet been investigated but will be in the near future. According to J. L. Biers[6] of Australia, after the hole has been collared, the noise level declines linearly from approximately 105 to 96 db, from a depth of 1 to 24 inches, then levels off.

There is an optimum operating thrust of the bit against the rock at which the penetration rate is a maximum and the noise level of a drill is minimum. Figure 4 shows the results of experiments by Dennis Irby[7] when the thrust on two jumbo drills is varied. The noise level varies about 2 db, and the penetration rate varies about 10 to 20 percent.

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[6]Work cited in footnote 5.

[7]Irby, D. H. Private communication, Feb. 16, 1973. Available upon request from C. R. Summers, Bureau of Mines, Pittsburgh, Pa., or from D. H. Irby, Bureau of Mines, Twin Cities, Minn.

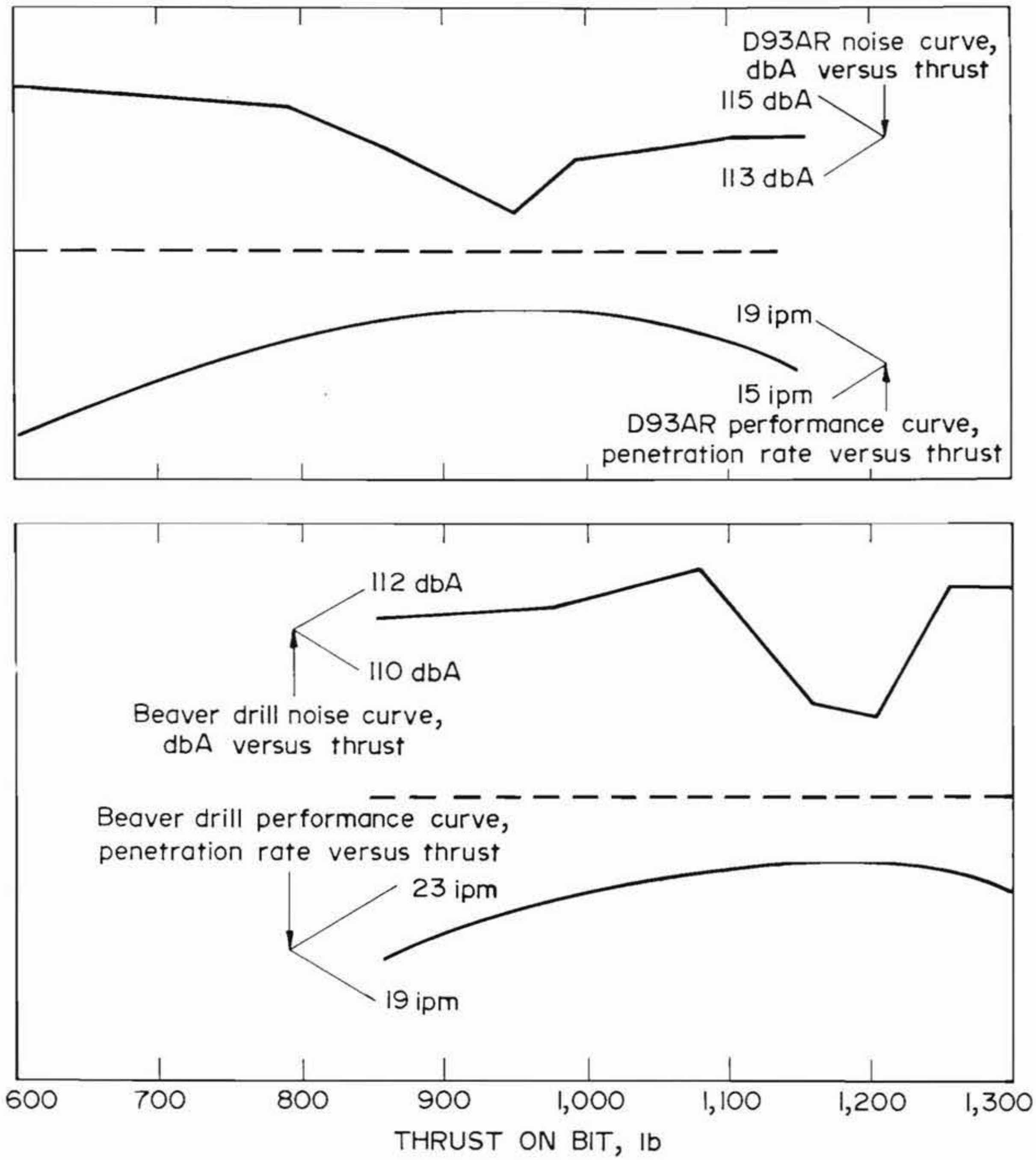

FIGURE 4. - Unmuffled drill performance and noise readings versus thrust in pounds.

The current Bureau of Mines investigations have been conducted by the Pittsburgh Mining and Safety Research Center for total drill noise control and by (1) U.S. Steel Engineers and Consultants[8] and (2) the Bureau of Mines Rolla Metallurgical Research Laboratory, Rolla, Mo.,[9] to develop noise abatement materials for, and methods of, abating the noise of pneumatic drills.

Several prototype mufflers were designed by U.S. Steel Engineers and Consultants and are shown in figure 5, the details of which are given in appendix A. Shown in figure 6 is an Atlas Copco BBC-17 drifter drill with constricted layer dampened rod, silenced by Rolla Metallurgy Research Center from 115 to 98 dbA. This report describes various combinations of controls that are applicable to current noise problems.

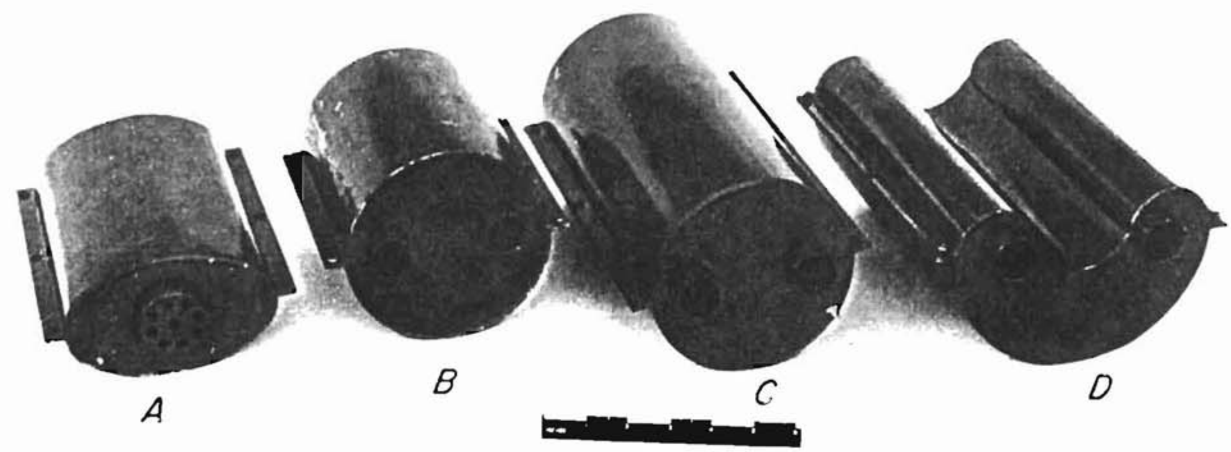

FIGURE 5. - Several prototype pneumatic drill exhaust mufflers using expansion and resonant chambers (with resultant dbA level on U.S. Steel drill): *A*, Muffler 1, 108 dbA; *B*, muffler 2, 105 dbA; *C*, muffler 3, 108 dbA; *D*, kidney-shaped muffler, 108 dbA.

[8]Manning, R. E. Muffler for Pneumatic Drill. BuMines Open File Rept. 28-73, 1973, 81 pp.; available for consultation at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and at Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 220 372.

[9]Visnapuu, A., and J. W. Jensen. Noise Control for the Pneumatic Rock Drill. Pres. at Ann. Meeting, Soc. Min. Eng., AIME, Chicago, Ill., Feb. 25-Mar. 1, 1973, SME Preprint 73-AU-62, 1973, 17 pp.

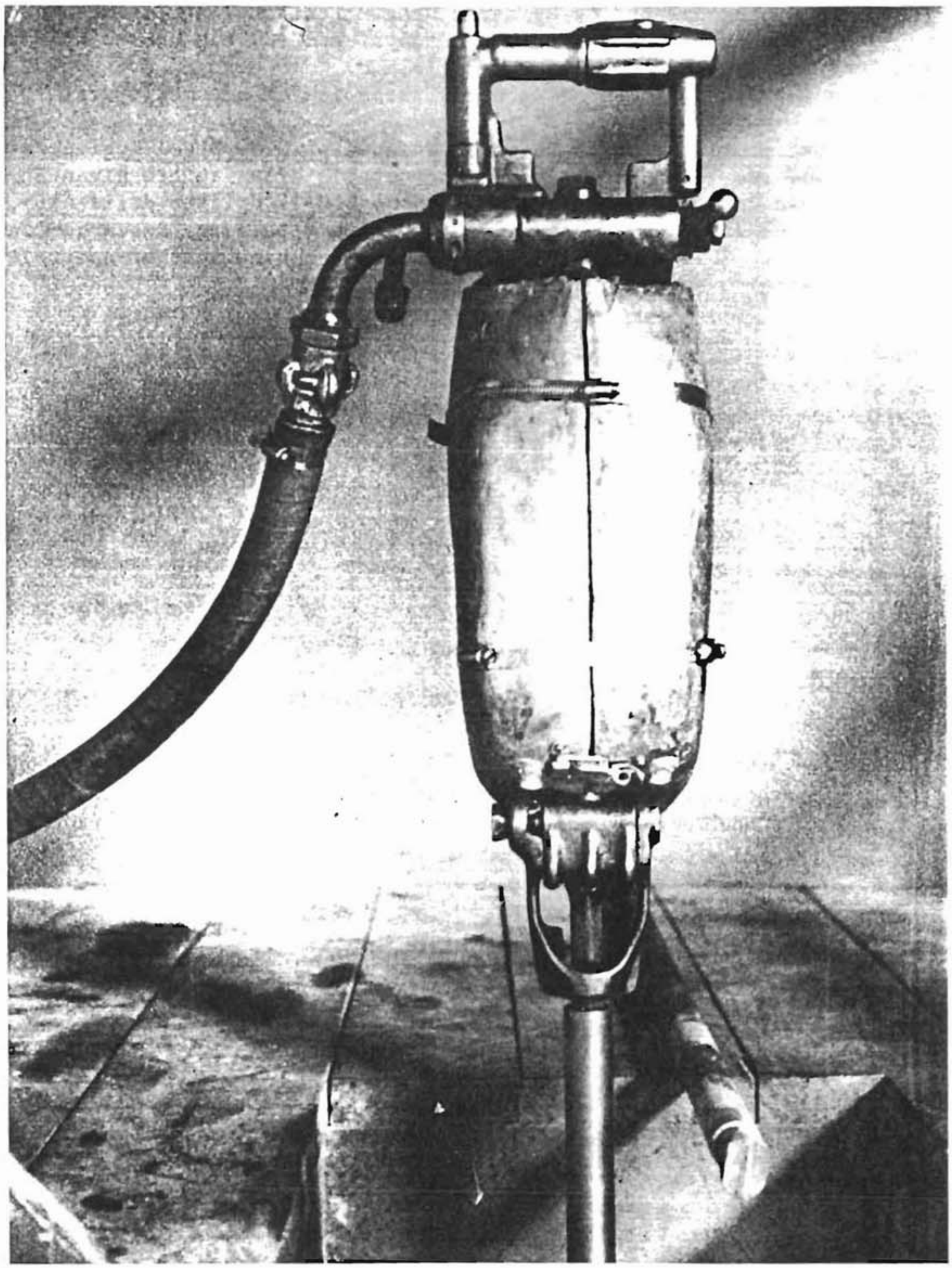

FIGURE 6. - Sinker drill silenced from 115 to 98 dbA.

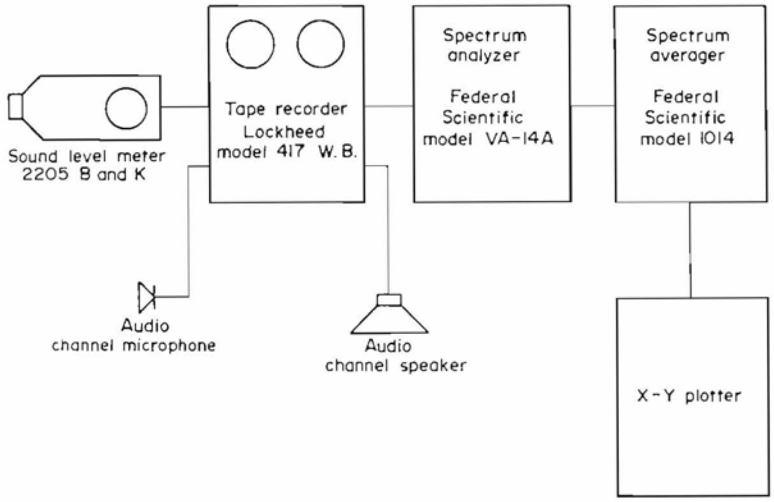

FIGURE 7. - Block diagram of instrumentation.

DATA COLLECTION AND PROCESSING

Sound level measurements of the drill noise were made with the drill in an open area to simulate free field operation. A pressure of 90 psig was supplied to the drill by a large compressor sufficiently isolated to register 83 dbC and 70 dbA at the drill site. This background noise would be 17 db below the noise of a 100-db drill and would contribute less than 0.2 db to the noise level.

Instrumentation shown in figure 7 consisted of a B&K 2205[10] sound level meter placed 1 meter to the side of the pneumatic drill. Visual readings of dbC and dbA were taken with the meter, and the meter output was cabled to a Lockheed 7-channel wide-band recorder, model 417 W.B. S/N 120, with a spectral response that was flat from 0 to 10 kHz at tape speed of 7.5 in/sec. Approximately one-half minute of drilling into sandstone was recorded, then the data from the recorder was analyzed with a Federal Scientific UA-14A spectrum analyzer, averaged by a spectrum averager, and recorded on an X-Y plotter.

Loading of the drill was effected by drilling into a 2-foot cube of sandstone. For the unload conditions, the drill was laid on its side on top of the sandstone cube. Overall calibration of the system employed a B&K piston phone model 4220 and a Wavetek signal generator model 114B.

EXPERIMENTAL PROCEDURE AND RESULTS

Two systems of abatement were attempted with the Ingersoll-Rand stoper: An integral muffler system, figure 8A, and a separate muffler system, figure 8B. The results are shown in table 4.

[10]Reference to specific products does not imply endorsement by the Bureau of Mines.

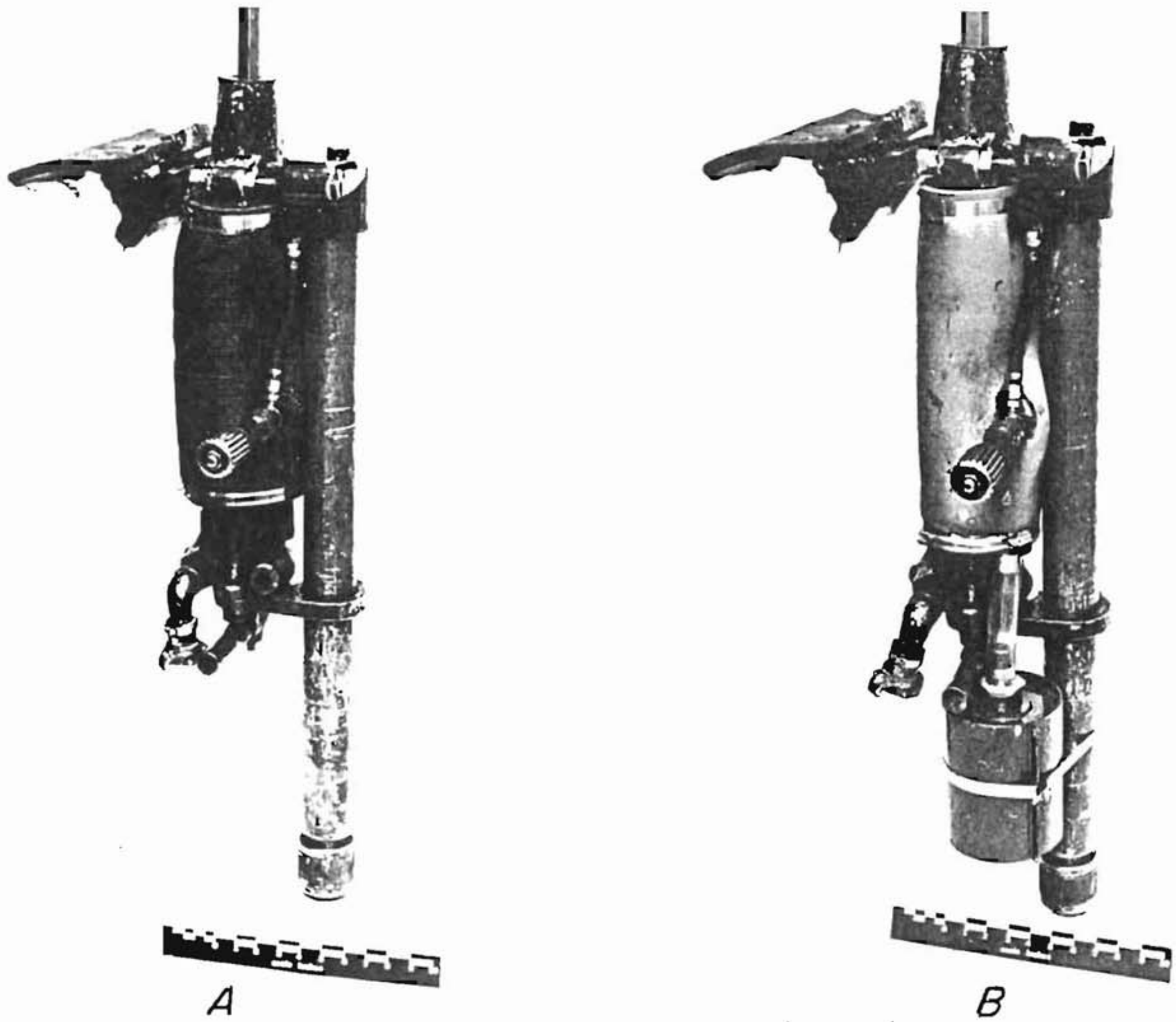

FIGURE 8. - Muffler systems: *A*, Integral; *B*, separate.

TABLE 4. - Two systems of noise abatement of an Ingersoll-Rand stoper

	Integral muffler system, dbA slow (fig. 9A)	Separate muffler system, dbA slow (fig. 9B)
Unloaded..................................	98	98
Loaded 41-inch drill rod with 6-inch constricted layer dampening..............	102	103
Loaded 41-inch drill rod with 6-inch constricted layer dampening and 27 inches of Tygon tubing..................	101	102

The integral muffler system employed a muffler cover made by Apex Equipment Inc. of Seattle, Wash. It is a cylinder of 1/2-inch-thick fiber-impregnated neoprene with end caps to fit the configuration of the drill body. The two ports in one end cap, for exhaust outlet, were modified by insertion of two metal tubes for improved muffling effect (fig. 9A). This muffler covered most of the drill casing sides. To cover the chuck end of the drill, a sheet-metal-covered layer of room-temperature cured urethane, Flexane,[11] was molded around the drill end to extend beyond the drill and encase the end of the drill rod, thereby abating airborne noise from the open chuck end. This practice was abandoned because of insignificant abating effect. The noise level from the unloaded drill with the foregoing abatement was reduced from 112 to 98 dbA. The resulting frequency analysis is shown in figure 10a. The noises from the vibrations of the drill rod were abated by molding a 6-inch

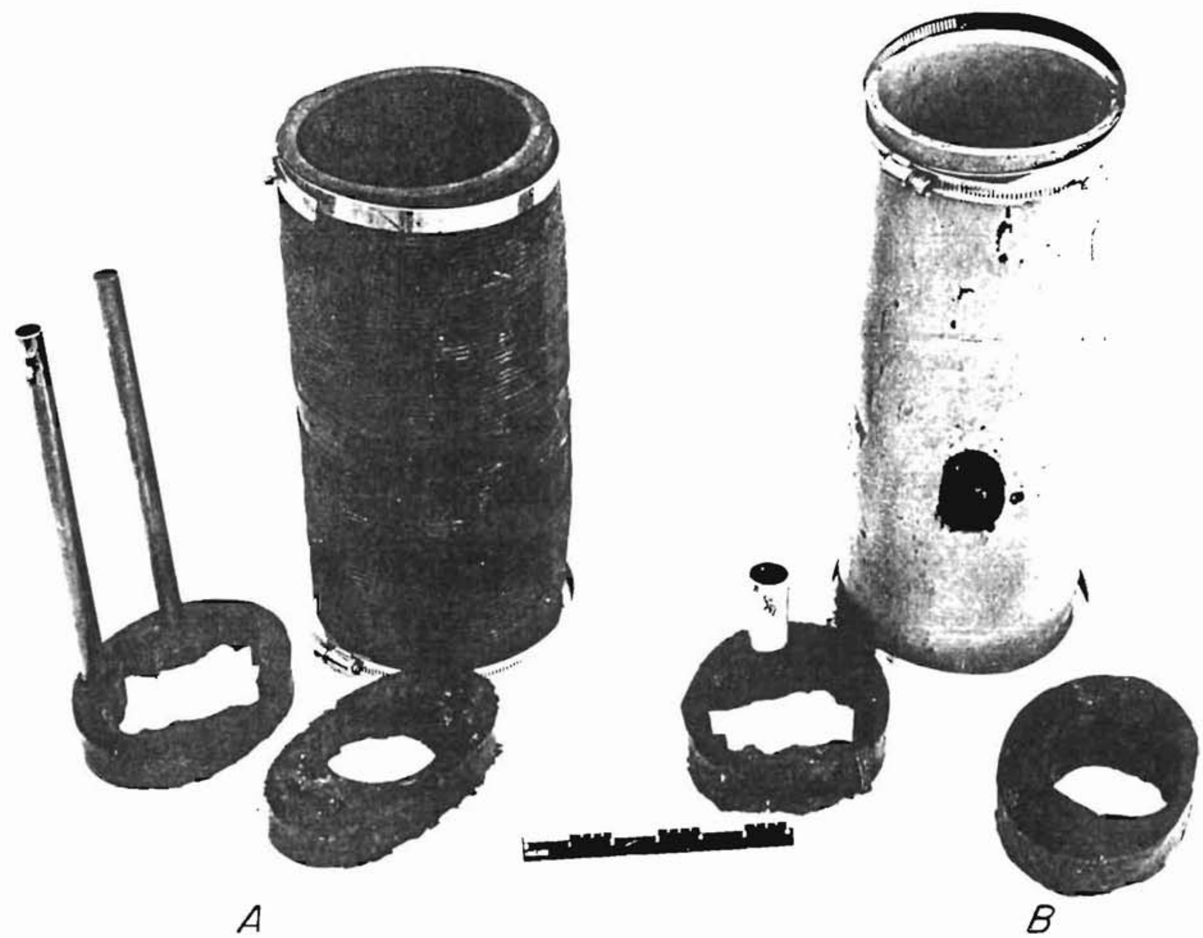

FIGURE 9. - Jackets for muffler systems: *A*, Integral; *B*, separate.

[11] Devcon Corp., Danvers, Mass.

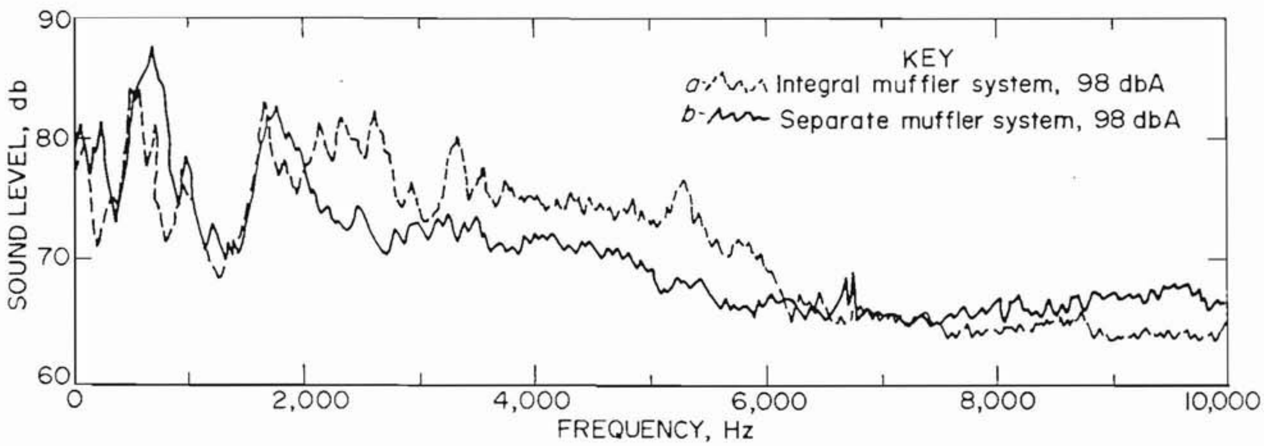

FIGURE 10. - Unloaded Ingersoll-Rand drill: *a*, Intergral muffler system, 98 dbA; *b*, separate muffler system, 98 dbA.

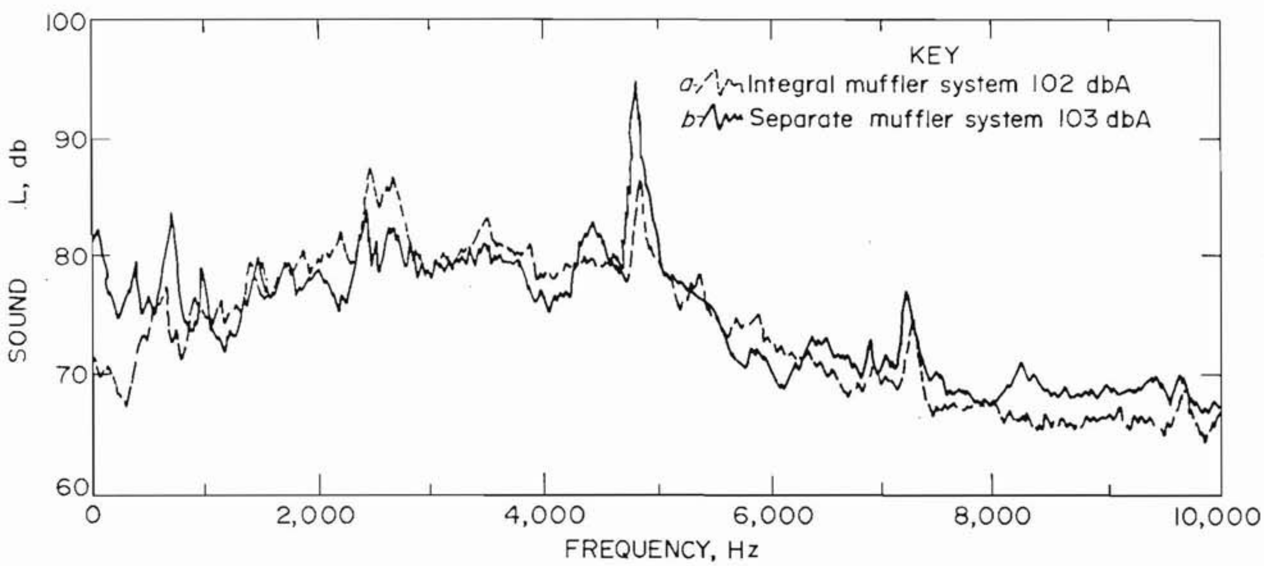

FIGURE 11. - Loaded Ingersoll-Rand drill: 41-inch drill rod with 6-inch constricted layer dampener; *a*, integral muffler system, 102 dbA; *b*, separate muffler system, 103 dbA.

length of Flexane encased in a steel tubing, about 4 inches from the chuck end of the rod. The ultimate noise level with all abatement employed using a 41-inch drill rod drilling into sandstone was 102 dbA (fig. 11a). When a 27-inch length of 1/8-inch-thick Tygon tubing was slipped over the remaining bare portion of the rod, the sound level was 101 dbA (fig. 12a). The separate muffler system (fig. 8B) applied to the same Ingersoll-Rand stoper employed the same shape of drill cover as the integral muffler system except that the terial was 1/4-inch-thick E-A-R energy absorbing material.[12] Also, in place

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~National Research Corp., Cambridge, Mass.

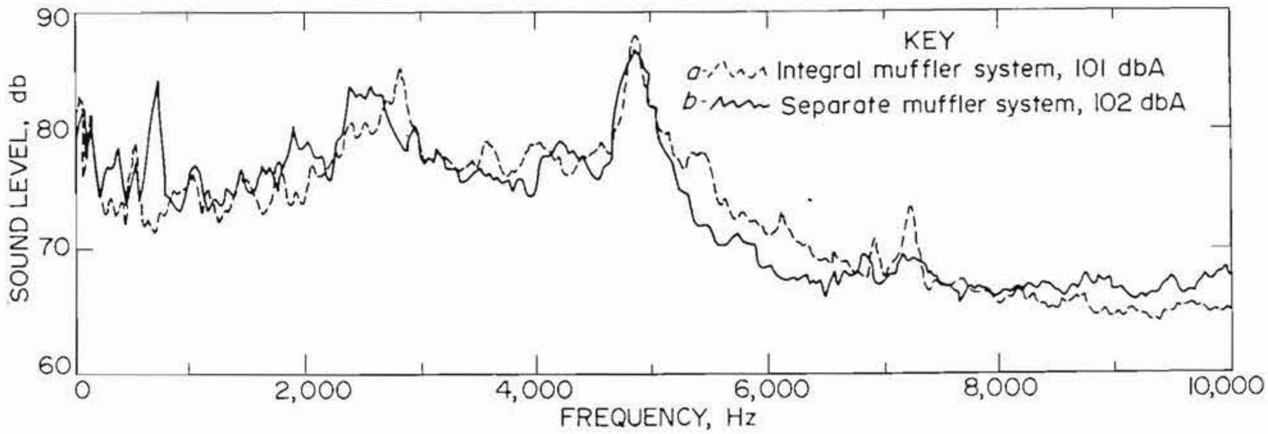

FIGURE 12. - Loaded Ingersoll-Rand drill: 41-inch drill rod with 6-inch constricted layer dampener and 27 inches of Tygon tubing; *a*, integral muffler system, 101 dbA; *b*, separate muffler system, 1C2 dbA.

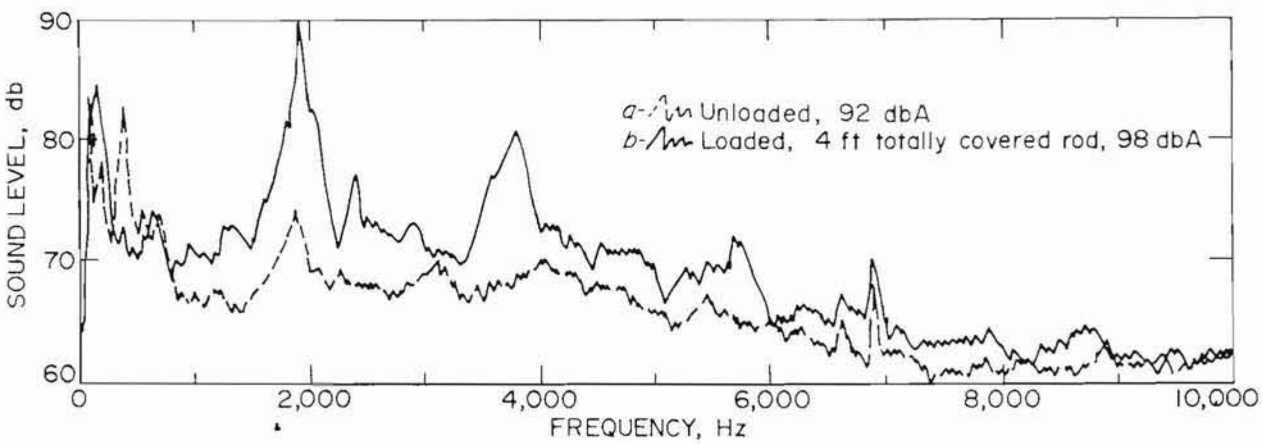

FIGURE 13. - Atlas Copco BBC-17 drill with rigid jacket muffler: *a*, Unloaded, 92 dbA; *b*, loaded, 4 ft totally covered rod, 98 dbA.

of the internal tubings, the exhaust port was brought out through a 1-inch-ID tube into an external muffler. The noise level of the unloaded drill at this point was again 98 dbA (fig. 10b). When the 41-inch dampened rod was used, drilling into sandstone, the noise level was 103 dbA (fig. 11b). Adding the 27 inches of Tygon to the rod lowered the level to 102 dbA (fig. 12b).

Rolla Metallurgy Research Center, Bureau of Mines, Rolla, Mo., delivered a prototype noise abated drifter drill, an Atlas Copco BBC-17 (fig. 6), to Pittsburgh Mining and Safety Research Center; the Rolla Metallurgy Research Center had abated the drill noise level from 115 dbA to within 98 dbA. The integral muffler drill casing consists of a 1/2-inch-thick aluminum honeycomb filled with a viscoelastic material, Ecofoam VIP,[13] and covered with an epoxy-type plastic aluminum for rigidity. Exhaust takes place through two internal

[13] Emerson and Cuming Inc., Canton, Mass.

tubings for further muffling effect. A noise abating alloy Cu-Mn, chuck liner, and rotational valve head have been substituted for steel parts. The drill steel noise was abated by application of a steel tubing encasing a layer of viscoelastic material the entire length of a 4-foot-drill rod. The noise level of this drill unloaded is 92 dbA (fig. 13a), and when loaded with the 4-foot constricted layer rod drilling sandstone, the noise level is 98 dbA (fig. 13b). It has been determined by Rolla Metallurgy Research Center that the penetration of the drill decreased proportionally with added length of constricted layer of the rod; consequently, this 4-foot totally covered rod reduced the penetration rate by 28 percent.

DISCUSSION OF RESULTS

In the unloaded tests of the Ingersoll-Rand stoper with a jacket to abate the noise from the drill body and a muffler to abate the exhaust noise, the two systems show no overall dbA slow difference as measured by a meter. When observing the frequency analysis curves of figure 11, a and b, the external muffler system is more effective in the frequencies below 6 kHz, but the integral muffler system has an advantage in the high frequencies, thereby equalizing the slow dbA response of 98 dbA for each system.

When a partially dampened rod is added to drill into sandstone, figure 11, a and b, the entire band of frequencies between 2.5 kHz and 5 kHz is raised similarly for both systems, and the dbA slow meter readings are similar at 102 and 103 dbA. It is postulated that this rise in the 2.5-kHz to 5-kHz band is due to part or all of three noise sources; namely, (1) impact of the piston and rod being transmitted through the case and cover, or perhaps airborne through the exhaust, (2) bit noise from collision of bit and rock, and (3) transverse rod vibration. In figure 12, a and b, when more dampening was applied, the middle of the 2.5-kHz to 5-kHz band was lowered, leaving the peaks at the ends of this band and lowering the overall dbA only 1 db; that is, to 101 and 102 dbA.

Examining the curves of figure 13, a and b, for the Atlas Copco noise-abated BBC-17 drill, two large peaks emerge at 2 kHz and 4 kHz; when loaded, drilling sandstone, this drill was 98 dbA as opposed to 92 dbA unloaded. In this instance, the drill rod is completely dampened with full-length constricted-layer dampening material, yet the two large peaks predominate the noise spectra, as in the case of the Ingersoll-Rand drill. It would appear then that those noise sources were the bit noise and/or mechanical impact noise of the piston and rod end within the drill body, not yet sufficiently abated.

CONCLUSION

When considering all the attributes of both systems--namely, integral muffler jacket and jacket with an external muffler--a prototype system was decided upon to include the integral muffler type using the E-A-R energy absorbing material for the jacket. This system is less awkward to handle and adds less weight to the drill. A complete set of instructions for installation is given in appendix B.

At this time, it is possible to abate the noise level of a 115-dbA stoper drill to a level of approximately 100 dbA. This would permit the drill operator about 2 hours of on time per 8-hour shift assuming no other exposure above 90 dbA. Additional operating time could be achieved through administrative control (rotating personnel) whenever feasible. To achieve lower levels of noise from a drill, more research is necessary to investigate the bit noise and to determine more efficient methods of abating mechanical noise.

APPENDIX A

U.S. Steel Research, under contract to the Bureau of Mines, designed and fabricated three muffler systems for a 75-lb-class drill (figs. A-1 through A-6). A fourth muffler, an innovative kidney-shaped version of the third system, was fabricated to fit neatly around the feed leg of a stoper drill (figs. A-7 through A-9).

The results of tests of the three systems are shown in tables A-1 and A-2. Muffler 2 was used in the Ingersoll-Rand stoper tests.

TABLE A-1. - Laboratory tests on prototype mufflers at U.S. Steel Research

Type of noise test	T_1, °F	T_2, °F	P_{c1}, psig	P_{c2}, psig	P_1, psig	P_2, psig	Noise, A scale, db
I. Exhaust-noise tests:							
A1. No muffler	115	30	95	90	75	-	114
A2. Muffler 1	110	25	95	90	75	-	88
A3. Muffler 2	120	45	95	90	75	-	85
A4. Muffler 3	125	55	95	90	75	-	87
B1. No muffler	105	30	120	118	100	-	115
B2. Muffler 1	130	50	128	125	100	-	90
B3. Muffler 2	135	55	128	124	100	-	87
B4. Muffler 3	135	60	127	123	100	-	90
II. Mechanical-noise tests:							
A. Muffler 1	130	60	92	88	75	-	104
B. Muffler 1	130	55	127	123	100	-	106
III. Total drill noise:							
A1. No muffler	103	28	92	88	75	0.17	115
A2. Muffler 1	120	45	92	88	75	1.99	103
A3. Muffler 2	115	48	92	88	75	2.02	104
A4. Muffler 3	105	30	92	88	75	1.60	104
B1. No muffler	115	28	128	126	100	.40	118
B2. Muffler 1	128	50	128	124	100	3.62	108
B3. Muffler 2	115	50	128	124	100	4.26	105
B4. Muffler 3	122	50	128	126	100	3.30	108
IV. Dust-collector noise:							
A1. Dust-intake noise	-	-	-	-	85	-	91
A2. Dust-intake and outlet noise	-	-	-	-	85	-	102
A3. Partial-dust-intake noise	-	-	-	-	85	-	88
B1. Dust-intake noise	-	-	-	-	100	-	92
B2. Dust-intake and outlet noise	-	-	-	-	100	-	102
B3. Partial-dust-intake noise	-	-	-	-	100	-	90

TABLE A-1. Laboratory tests on prototype mufflers at U.S. Steel Research--Continued

Type of noise test	T_1, °F	T_2, °F	P_{c1}, psig	P_{c2}, psig	P_1, psig	P_2, psig	Noise, A scale, db
V. Wall-transmission noise:							
A. Without muffler..................	-	-	-	-	100	-	84
B. With muffler.....................	-	-	-	-	100	-	77
VI. Simulated-noise tests:							
1. No muffler.......................	-	-	-	-	-	-	96
2. Muffler 1........................	-	-	-	-	-	-	77
3. Muffler 2........................	-	-	-	-	-	-	75
4. Muffler 3........................	-	-	-	-	-	-	75

NOTES.--P_1 Inlet air pressure of pneumatic drill.
P_2 Exhaust air pressure of pneumatic drill.
P_c Compressor exhaust pressure.
P_{c1} Compressor exhaust pressure when drill piston is not operating.
P_{c2} Compressor exhaust pressure when drill piston is operating.
T_1 Inlet air temperature to pneumatic drill.
T_2 Exhaust air temperature of pneumatic drill.

TABLE A-2. - Field tests on prototype mufflers

Testing arrangement of mufflers	Sound-pressure level[1] (A scale), db	T_2,[2] °F
No muffler.........................	112-115	-10 to -4
Muffler 1..........................	103-105	3 to 10
Muffler 2..........................	100-104	4 to 10
Muffler 3..........................	102-103	0 to 1
Ambient (drill not operating)......	83	75

[1] This sound-pressure level includes mechanical noise.
[2] Exhaust air temperature of pneumatic drill.

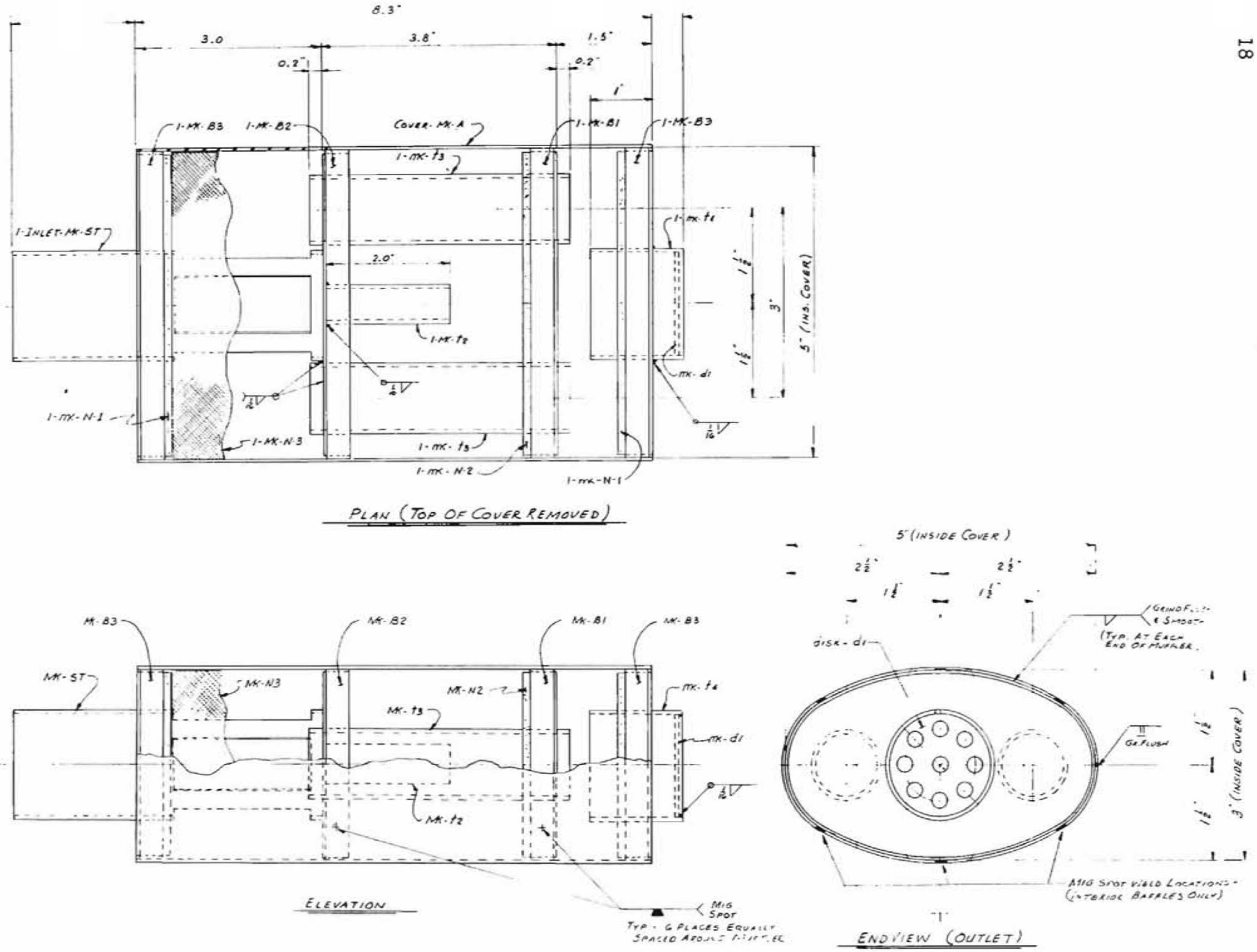

FIGURE A-1. - Muffler 1 diagram.

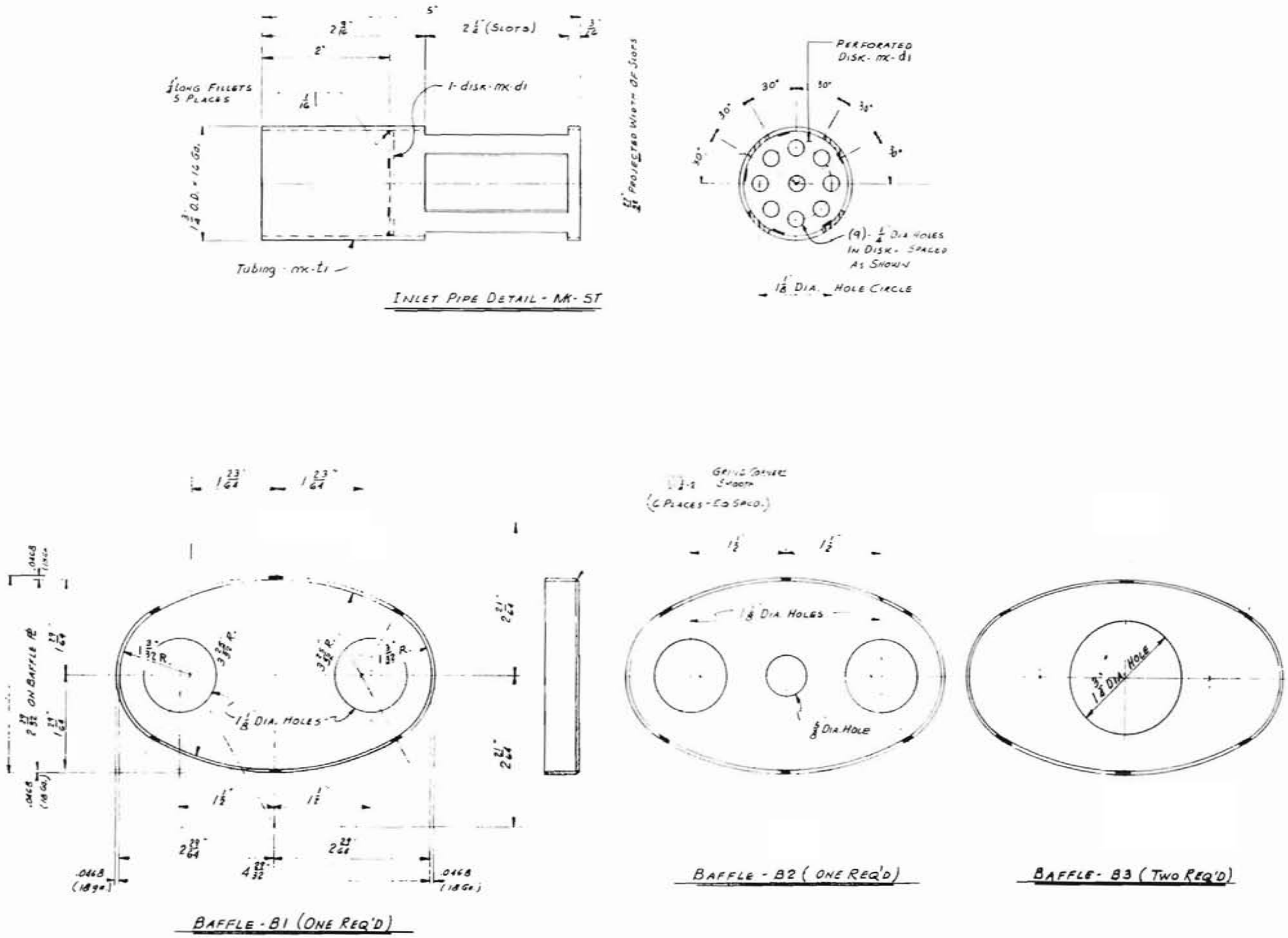

FIGURE A-1. - Muffler 1 diagram.—Continued

BILL OF MATERIAL			
Nº REQ'D	MK.	DESCRIPTION	REMARKS
1	A	COVER - 8.3" × 18 Ga. (.0468) × 12 3/4" LONG	BEND TO SUIT BAFFLE PLs.
1	B1	BAFFLE ~ 2 29/32 × 18 Ga. (.0468) × 4 29/32	
1	a	Flange Bar - 3/8 × 18 Ga. (.0468) × 12 11/16"	Bend To Suit Baffle B1
1	B2	BAFFLE - 2 29/32 × 18 Ga. (.0468) × 4 29/32	
1	a	FLange Bar - 3/8 × 18 Ga. (.0468) × 12 11/16	BEND TO SUIT BAFFLE B2
2	B3	BAFFLE - 2 29/32 × 18 Ga. (.0468) × 4 29/32	
2	a	FLANGE Bar - 3/8 × 18 Ga. (.0468) × 12 11/16	BEND TO SUIT BAFFLE B3
1	ST	INLET PIPE - CONSISTING OF :-	
1	t1	Tubing - 1 3/4" O.D. × 16 Ga. (.0625) × 0'-5"	
1	d1	DISK - 1 5/8" DIA. × 16 Ga. (.0625)	PERFORATED
1	t2	Tubing - 5/8" O.D. × 16 Ga (.0625) × 0'-2"	
2	t3	Tubing - 1 1/8" O.D. × 16 Ga. (.0625) × 4.2"	
1	t4	tubing - 1 3/4" O.D. × 16 Ga. (.0625) × 1 1/2"	
1	d1	DISK - 1 5/8" DIA. × 16 Ga. (.0625)	PERFORATED
2	N-1	NEOPRENE LINER 3" × 5" OVAL × 1/2" TK. (CUT TO Same dim. As BAFFLE P. B3)	
1	N-2	NEOPRENE LINER 3" × 5" OVAL × 1/2" TK. (CUT TO SAME DIM. AS BAFFLE P. B1)	
1	N-3	NEOPRENE LINER 2 7/16" WIDE × 1/2" × 12 5/8" LONG	
		NOTE: N-1, N-2, & N-3 TO BE CUT FROM 1/2 THK. SHEET AS FURNISHED BY TOYAD CORP., LATROBE, PA., 15650 PHONE:- 412-537-7754; KNOWN AS "UPDOWN RF NEOPRENE LATEX FOAM."	
—	AD	TO BOND NEOPRENE LINERS TO SHELL & TO EACH OTHER, USE "DURO-PLASTIC E-POX-E" AS SUPPLIED BY WOODHILL CHEM. SALES CORP., CLEVELAND, 44128, OHIO	

FIGURE A-2. - Muffler 1 bill of material.

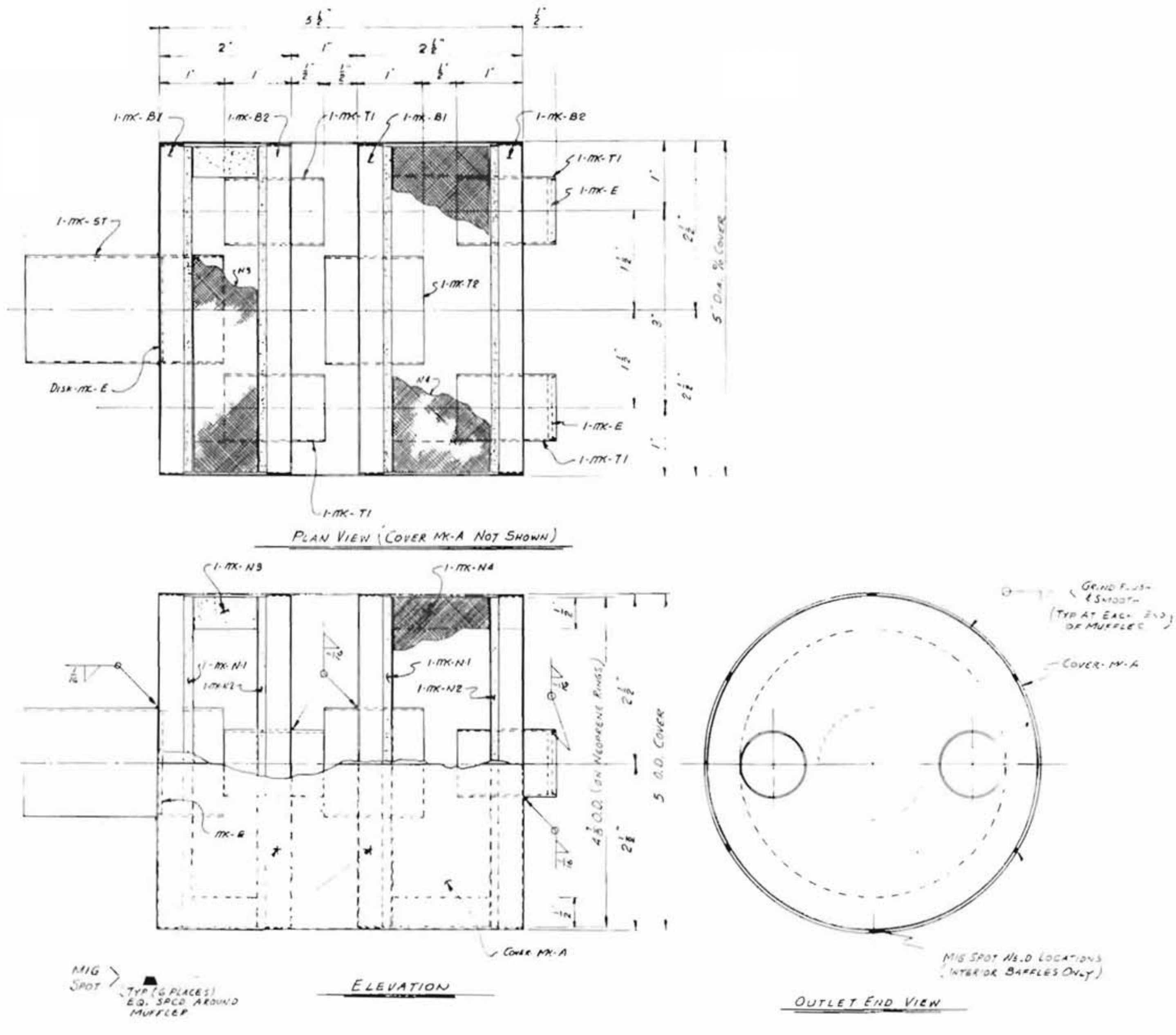

FIGURE A-3. - Muffler 2 diagram.

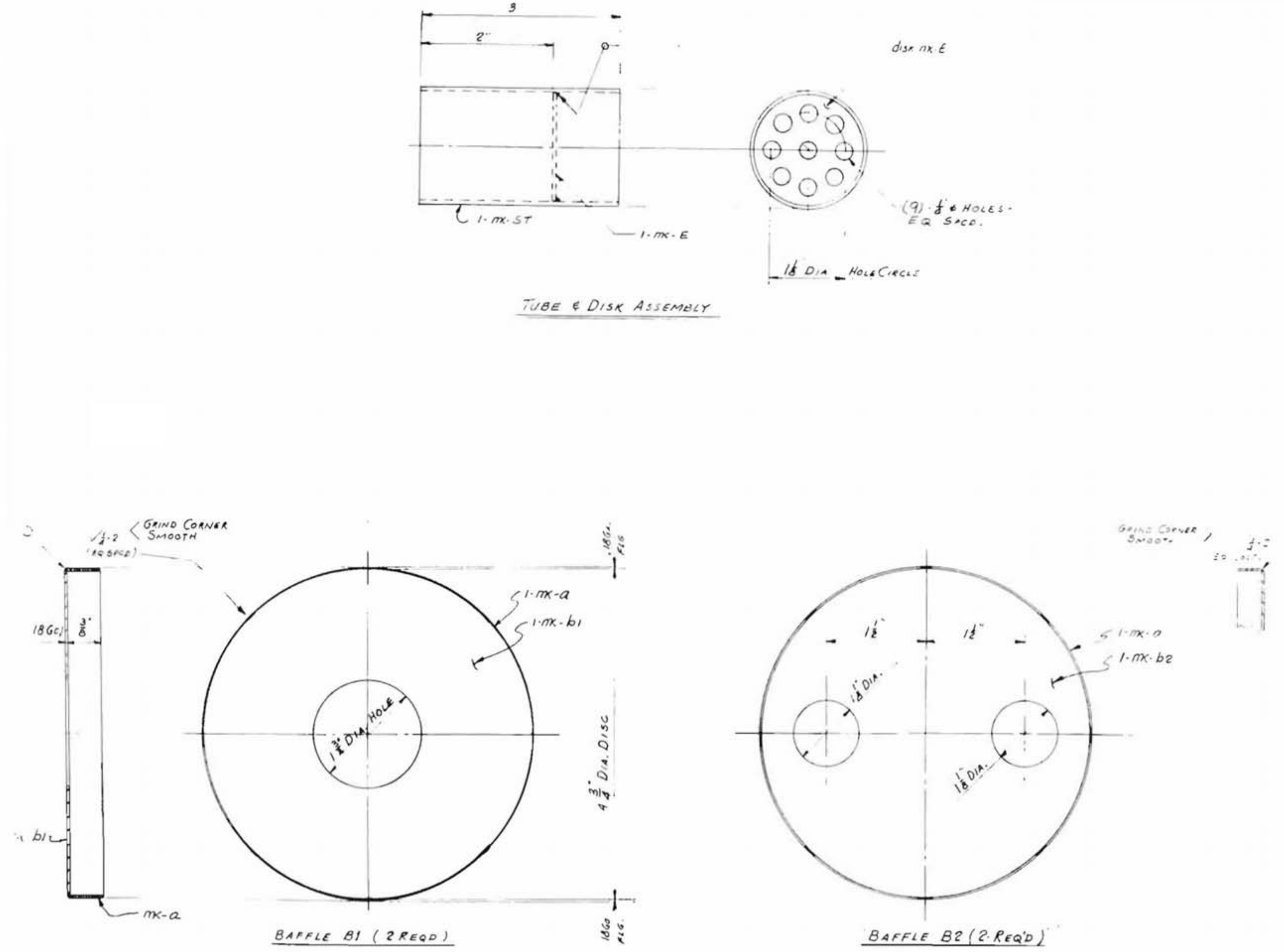

FIGURE A-3. - Muffler 2 diagram.—Continued.

BILL OF MATERIAL			
Nº REQ'D	MK	DESCRIPTION	REMARKS
1	A	COVER - TUBING - 5" O.D. × 16 GA (.0625) WALL × 5 1/2" LONG	
2	B1	BAFFLE - 4 3/4" DIA. × 18 Ga. (.0468)	
2	a	FLG. RING - 3/8" × 18 Ga. (.0468) × 1'-3 1/4"	
2	B2	BAFFLE - 4 3/4" DIA. × 18 Ga (.0468)	
2	a	FLG. RING - 3/8" × 18 Ga. (.0468) × 1'-3 1/4"	
1	ST	TUBING - 1 3/4" O.D. × 16 Ga. (.0625) WALL × 3" LONG	
4	T-1	TUBING - 1.125" O.D. × 16 Ga. (.0625) Wall × 1 1/2" LONG	
1	T2	TUBING - 1 3/4" O.D. × 16 Ga. (.0625) Wall × 1 1/2" LONG	
1	E	1 5/8" DIA. × 16 Ga. (.0625) PERFORATED DISK	
2	N-1	NEOPRENE LINER 4 3/4" DIA. × 1/2" THICK (CUT TO SAME DETAIL AS BAFFLE B1)	
2	N2	NEOPRENE LINER 4 3/4" DIA. × 1/2" THICK (CUT TO SAME DETAIL AS BAFFLE B2)	
1	N-3	NEOPRENE RING 7/8" Wide × 1'-2 1/8" LONG	
1	N-4	NEOPRENE RING 1 3/8" WIDE × 1'-2 1/8 LONG (NOTE: N1, N2, N3, & N4 TO BE CUT FROM 1/2" THICK SHEETING AS FURN. BY TOYAD CORPORATION, LATROBE, PA, 15650, Phone:- 412-537-7754 ; KNOWN AS "UPDOWN RP NEOPRENE LATEX FOAM"	
—	AD	TO BOND NEOPRENE LINERS TO SHELL & TO EACH OTHER USE "DURO-PLASTIC E-POX-E" AS SUPPLIED BY WOODHILL CHEM. SALES CORP., CLEVELAND, 44128, OHIO	

FIGURE A-4. - Muffler 2 bill of material.

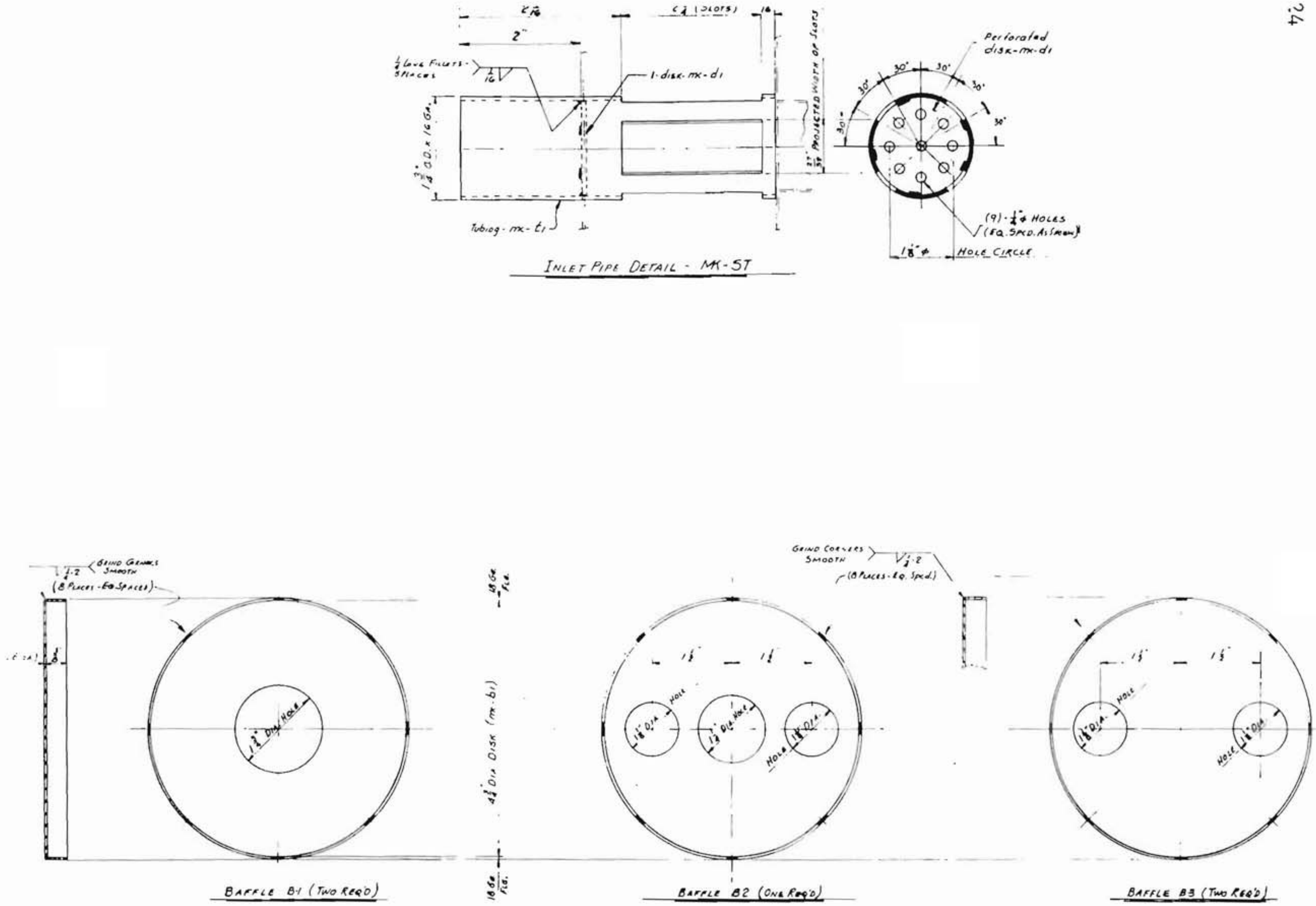

FIGURE A-5. - Muffler 3 diagram.

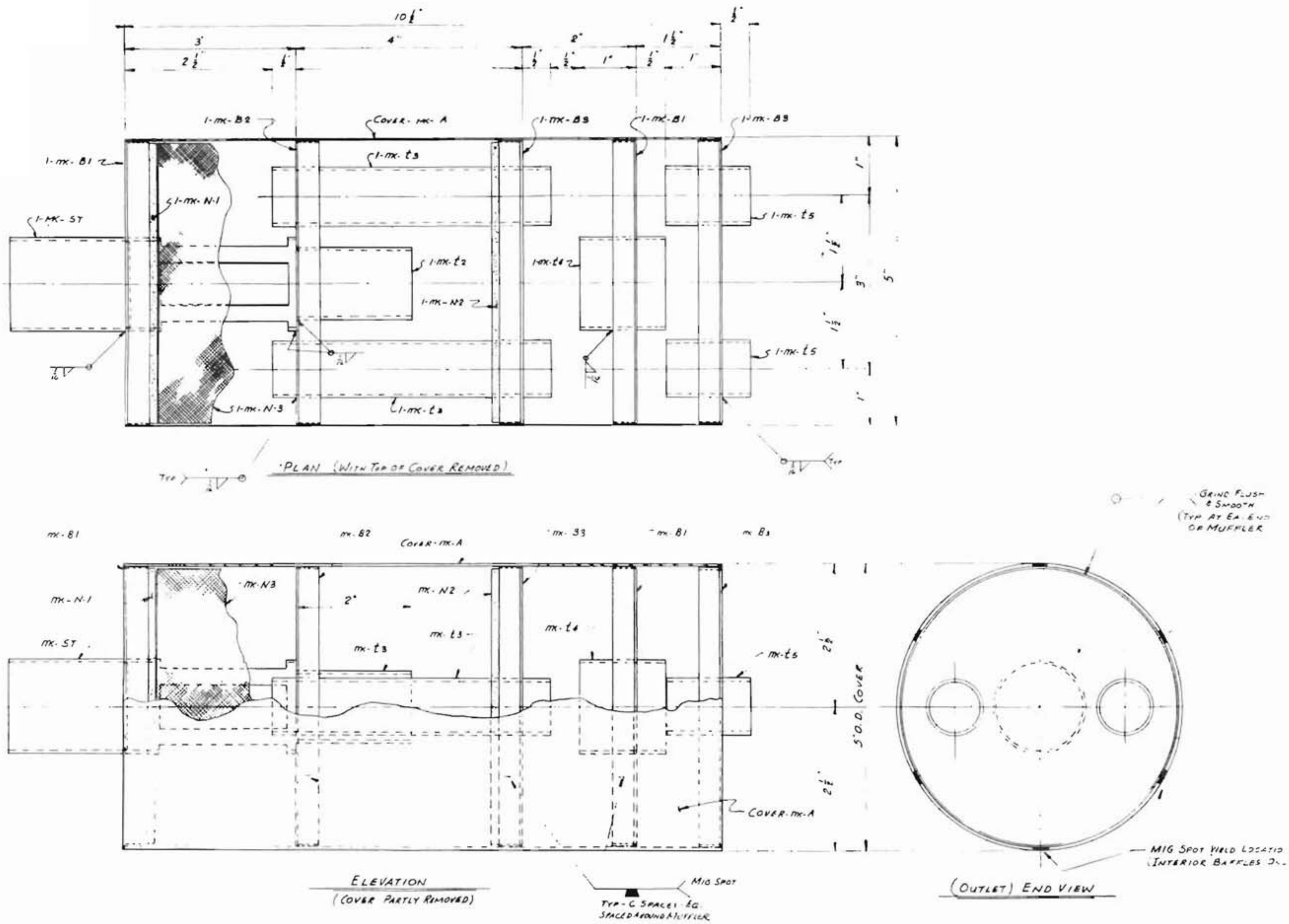

FIGURE A-5. - Muffler 3 diagram.–Continued.

BILL OF MATERIAL

Nº REQ'D	MK	DESCRIPTION	REMARKS
1	A	COVER - TUBING - 5" O.D. × 16 GA. (.0625)	WALL × 0'-10½" LONG.
2	B1	BAFFLE 4¾ ϕ × 18 GA. (.0468)	
2	a	Flange Ring - 3/8 × 18 Ga. (.0468) × 1'-3¼"	
1	B2	BAFFLE - 4¾ DIA. × 18 GA. (.0468)	
1	a	Flange Ring - 3/8 × 18 GA. (.0468) × 1'-3¼"	
2	B3	BAFFLE - 4¾" DIA. × 18 GA (.0468)	
2	a	Flange RING - 3/8 × 18 GA (.0468) × 1'-3¼"	
1	ST	INLET PIPE CONSISTING OF:-	
1	t1	TUBING 1¾" O.D. × 16 GA. (.0625) × 0'-5" LONG	
1	d1	disk - 1 5/8" DIA. × 16 GA. (.0625) - PERFORATED	
1	t2	Tubing - 1 3/8" O.D. × 16 Ga. (.0625) × 2" LONG	
2	t3	Tubing - 1 1/8" O.D. × 16 Ga. (.0625) × 5" LONG	
1	t4	Tubing - 1 3/4" O.D. × 16 Ga. (.0625) × 1 1/2" LONG	
2	t5	Tubing - 1 1/8" O.D. × 16 Ga. (.0625 × 1 1/2" LONG	
1	N-1	NEOPRENE LINER 4¾" DIA. × ½" THICK (CUT TO SAME DETAIL AS BAFFLE "B1")	
1	N-2	NEOPRENE LINER 4¾" DIA. × ½" THICK (CUT TO SAME DETAIL AS BAFFLE "B3")	
1	N-3	NEOPRENE LINER 2 7/16" Wide × ½" TK. × 1'-2 1/8" LONG (NOTE: N-1, N-2, & N-3 TO BE CUT FROM ½" TK. SHEETING AS FURNISHED BY TOYAD CORP., LATROBE, PA., 15650, Phone:- 412-537-7754; KNOWN AS "UPDOWN RP NEOPRENE LATEX FOAM."	
—	AD	TO BOND NEOPRENE LINERS TO SHELL & TO EACH OTHER USE "DURO-PLASTIC E-POX-E" AS SUPPLIED BY WOODHILL CHEM. SALES CORP., CLEVELAND, 44128, OHIO.	

FIGURE A-6. - Muffler 3 bill of material.

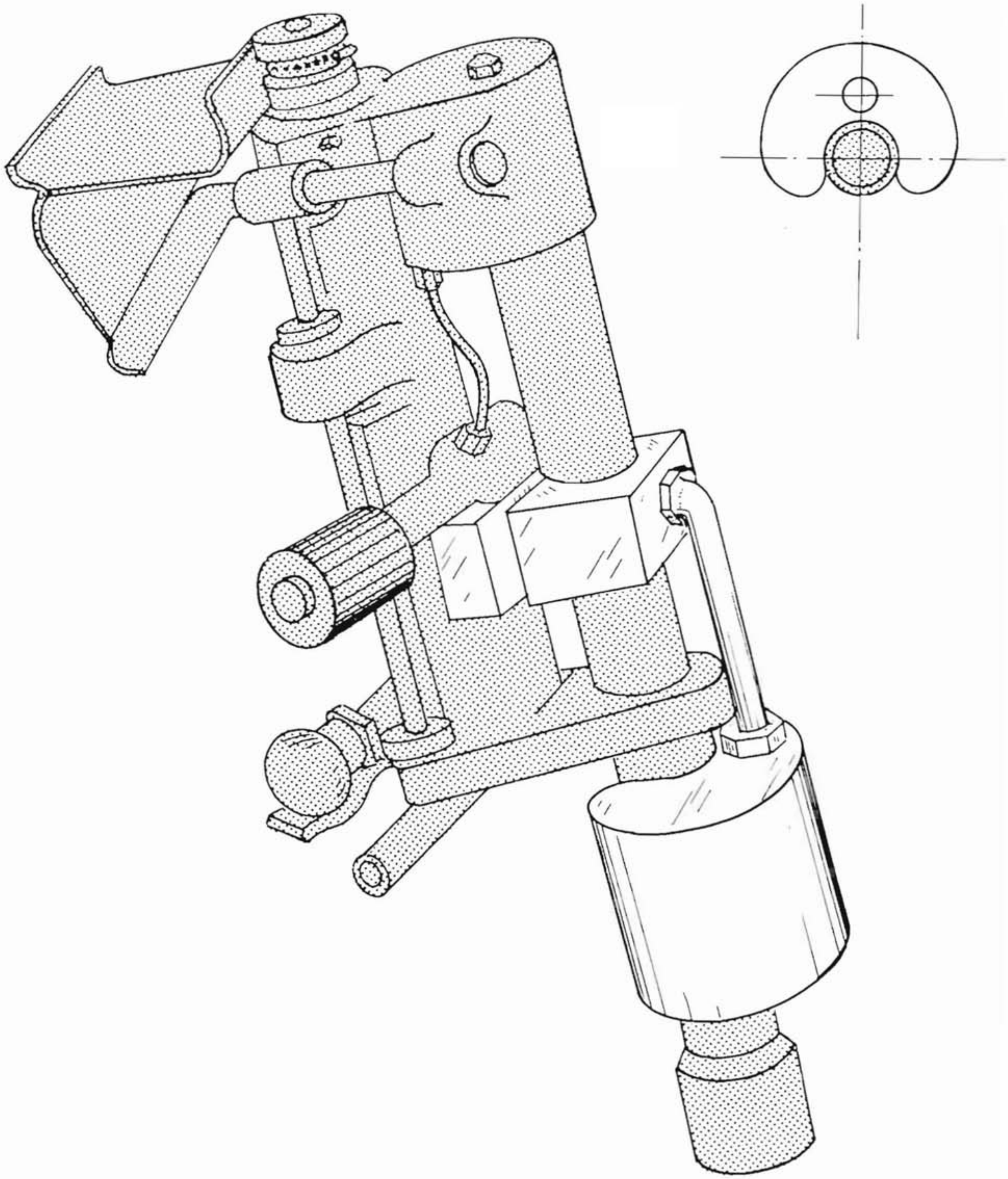

FIGURE A-7. - U.S. Steel muffler concept for pneumatic drill.

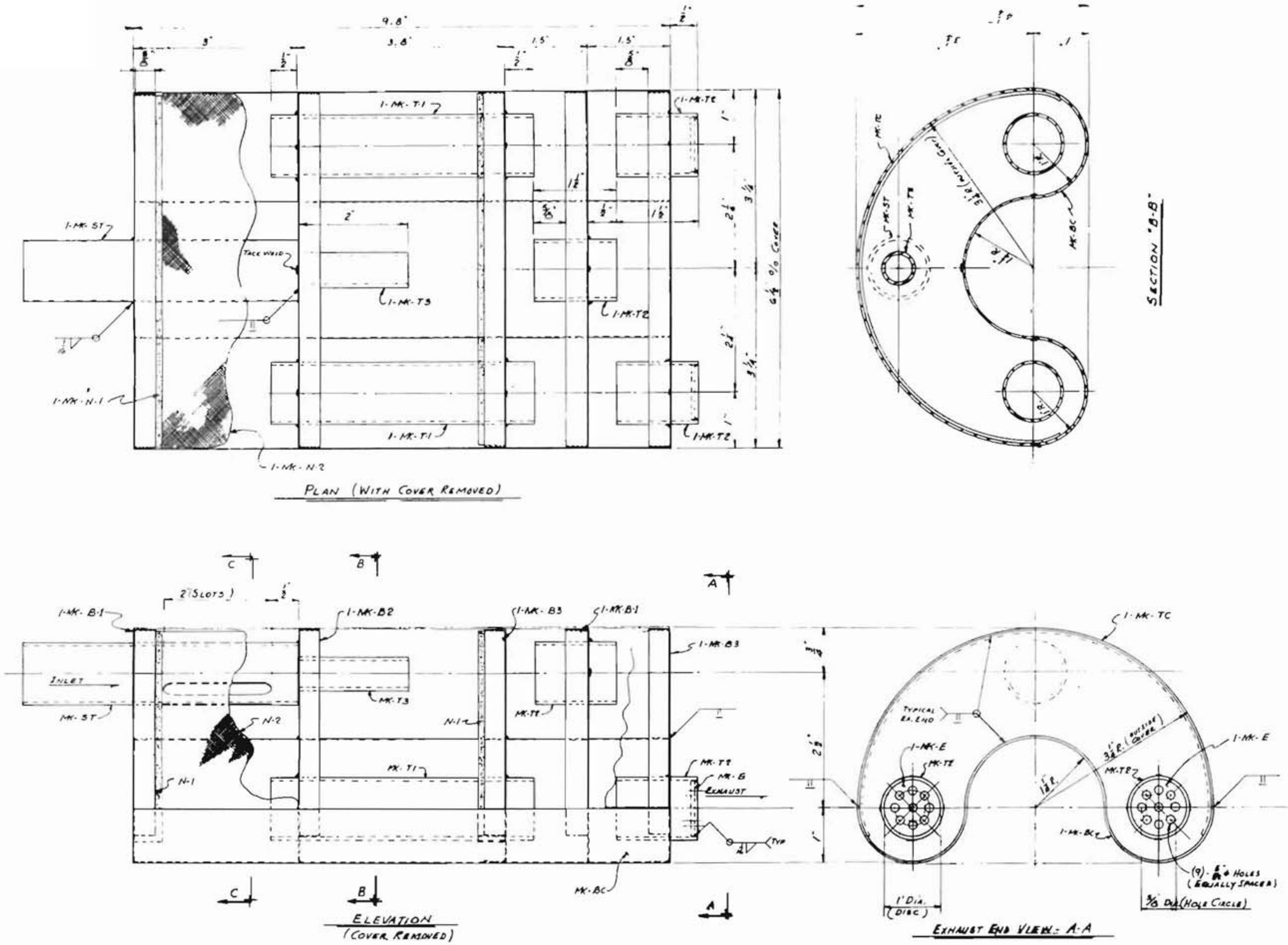

FIGURE A-8. - Kidney-shaped-muffler diagram.

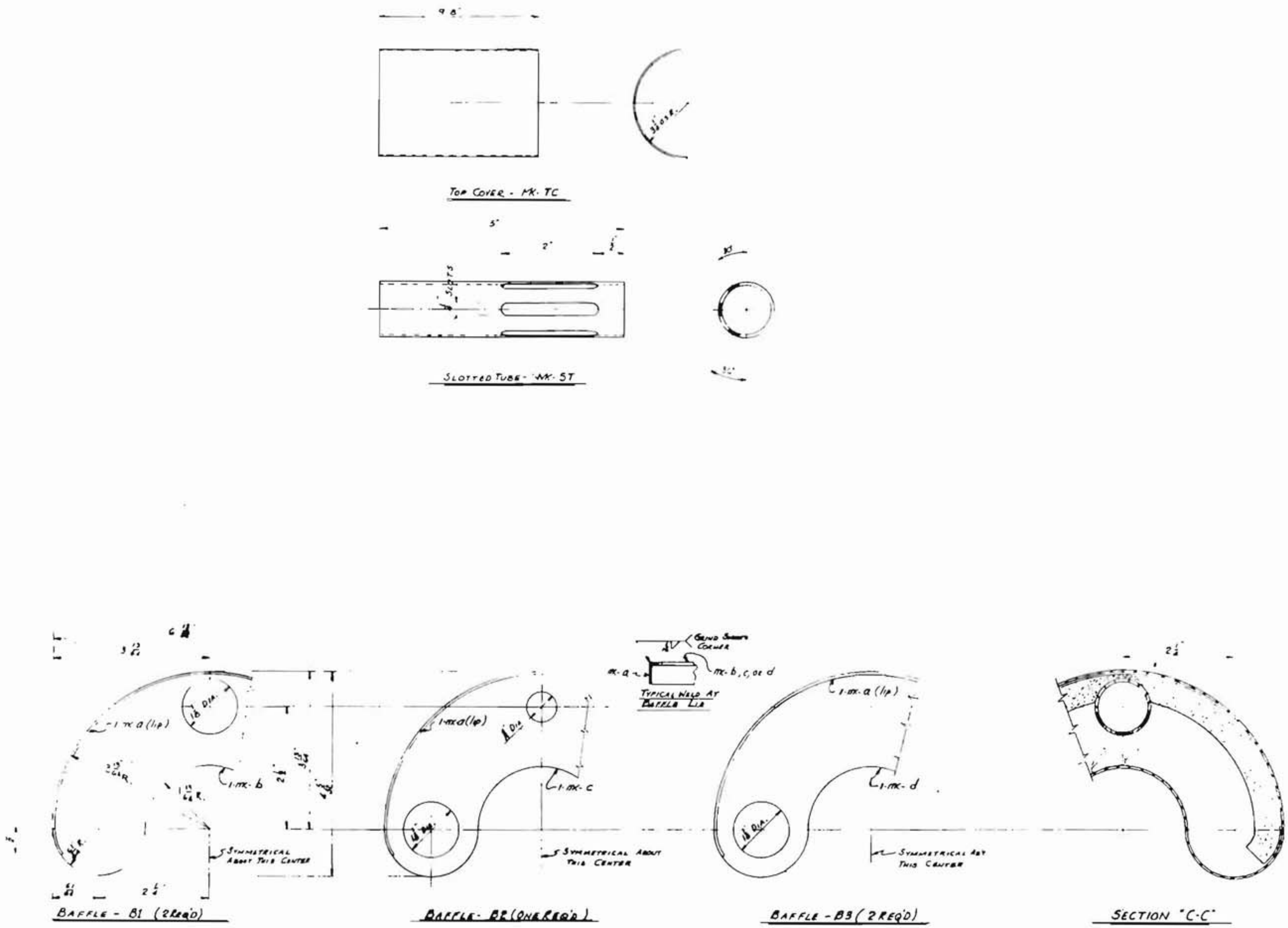

FIGURE A-8. - Kidney-shaped-muffler diagram.–Continued.

BILL OF MATERIAL

No. REQ'D	MK.	DESCRIPTION	REMARKS
1	TC	TOP COVER - 9.8" × 18 Ga. (.0478) × 10.09" LONG	
1	ST	TUBING 1.125 O.D × 16 GA (.0625) × 0'-5" LONG	
2	T-1	TUBING 1.125 O.D × 16 GA (.0625) × 0'-4.8" LONG	
3	T-2	TUBING 1.125 O.D. × 16 GA. (.0625) × 1½" LONG	
1	T-3	PC. ½" I.D × ⅝ O.D TUBING × 0'-2" LONG	
2	B1	BAFFLES	
2	b	4 5/32 × 18 Ga. (.0478) × 6 13/32"	
2	a	3/8 × 18 Ga. (.0478) × 11.09" LONG	(Lip)
1	B2	BAFFLES	
1	c	4 5/32 × 18 Ga. (.0478) × 6 13/32"	
1	a	3/8 × 18 Ga. (.0478) × 11.09" LONG	(Lip)
2	B3	BAFFLES	
2	d	4 5/32 × 18 Ga. (.0478) × 6 13/32"	
2	a	3/8 × 18 Ga. (.0478) × 11.09" LONG	(Lip)
2	E	1" DIA. × 16 Ga (.0625) PERFORATED DISK	
2	N-1	NEOPRENE LINER - 4⅛ × ½ × 6 13/32, Cut [illegible] Baffles B1 & B3;	
1	N-2	NEOPRENE LINER 2½ × ½ × 11¼ (NOTE - N1 & N2 TO BE CUT FROM ½" THICK SHEETING AS FURNISHED BY - TOYAD CORPORATION, LATROBE, PA, 15650; [illegible] 4[illegible]-537-7754, KNOWN AS "UPDOWN RP NEOPRENE LATEX FOAM";	
—	AD	TO BOND NEOPRENE LINERS TO SHELL & TO EACH OTHER USE "DURO-PLASTIC E-POX-E" AS SUPPLIED BY WOODHILL CHEM. SALES CORP., CLEVELAND, 44128, OHIO.	
1	BC	BOTTOM COVER 7 1/16 × 18 Ga. (.0478) × 9.8" LONG	

FIGURE A-9. - Kidney-shaped-muffler bill of material.

APPENDIX B

Fabrication of a Jacket Muffler and a Damped Drill Rod

Two different sleeves were used for the drill noise abatement project. The first sleeve, shown in figure B-1, was a seamless neoprene sleeve, bought from Apex Equipment Inc., Seattle, Wash. Apex will provide end caps if a template of the drill body is provided. This seamless sleeve presents a problem of removal for repair of the drill.

The second (and recommended) sleeve (fig. B-2) was made from a sheet of 1/4-inch-thick C-1002 E-A-R energy absorbing material manufactured by National Research Corp. of Cambridge, Mass. The sheet was cut to size to create a cylinder or sleeve of approximately 5-1/2-in ID and 15 in long, as shown in figure B-3. The edges were fastened together by means of an extruded aluminum H cross section, the end view of which is shown in figure B-4. One edge was drilled and pop-riveted for permanent fastening (fig. B-5), and the other was drilled and fastened with metal self-tapping screws for easy removal.

FIGURE B-1. - Jacket sleeve manufactured by Apex Equipment Inc.

FIGURE B-2. - Jacket sleeve of 1/4-inch C-1002 E-A-R energy absorbing material with joint H cross-section aluminum extrusion.

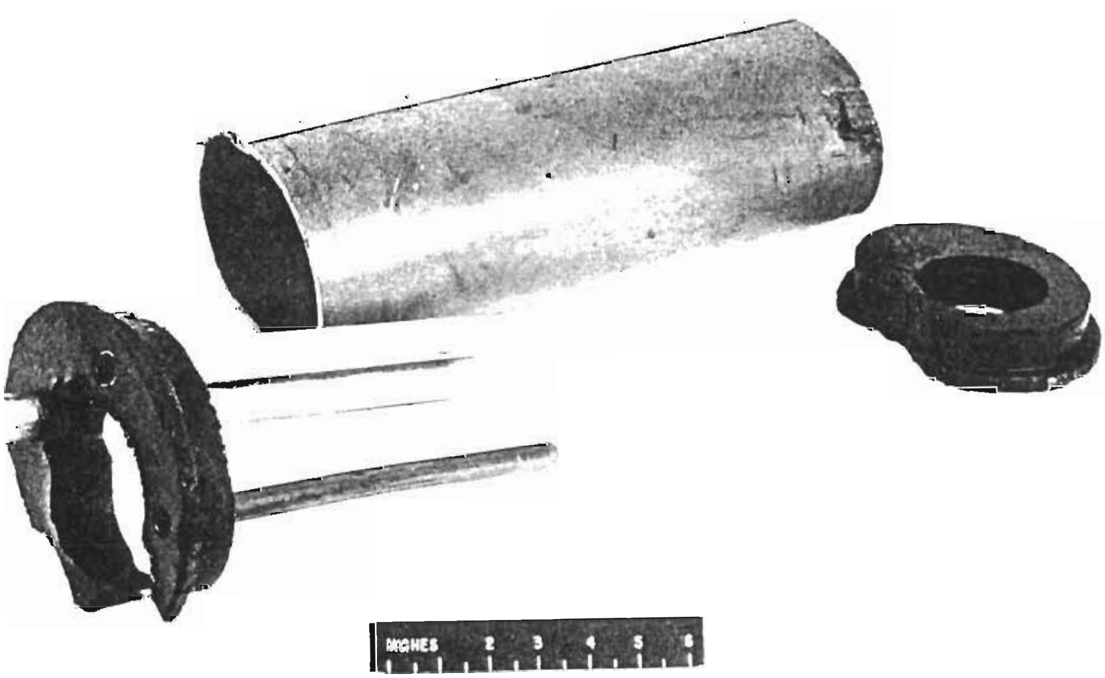

FIGURE B-3. - Jacket sleeve joined with aluminum fastener, end caps, and exhaust tubes.

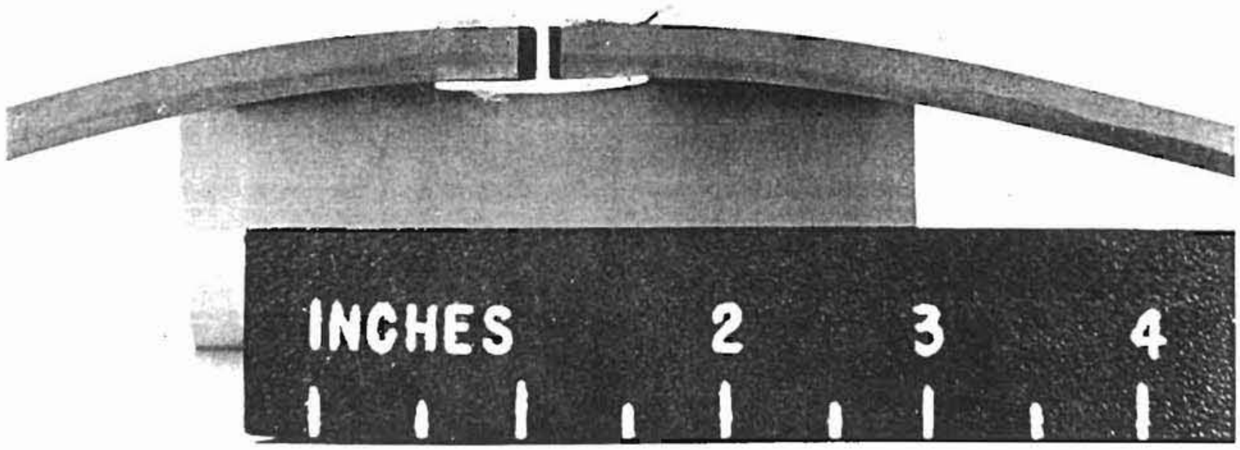

FIGURE B-4. - End view of H cross-section fastener with abating material inserted.

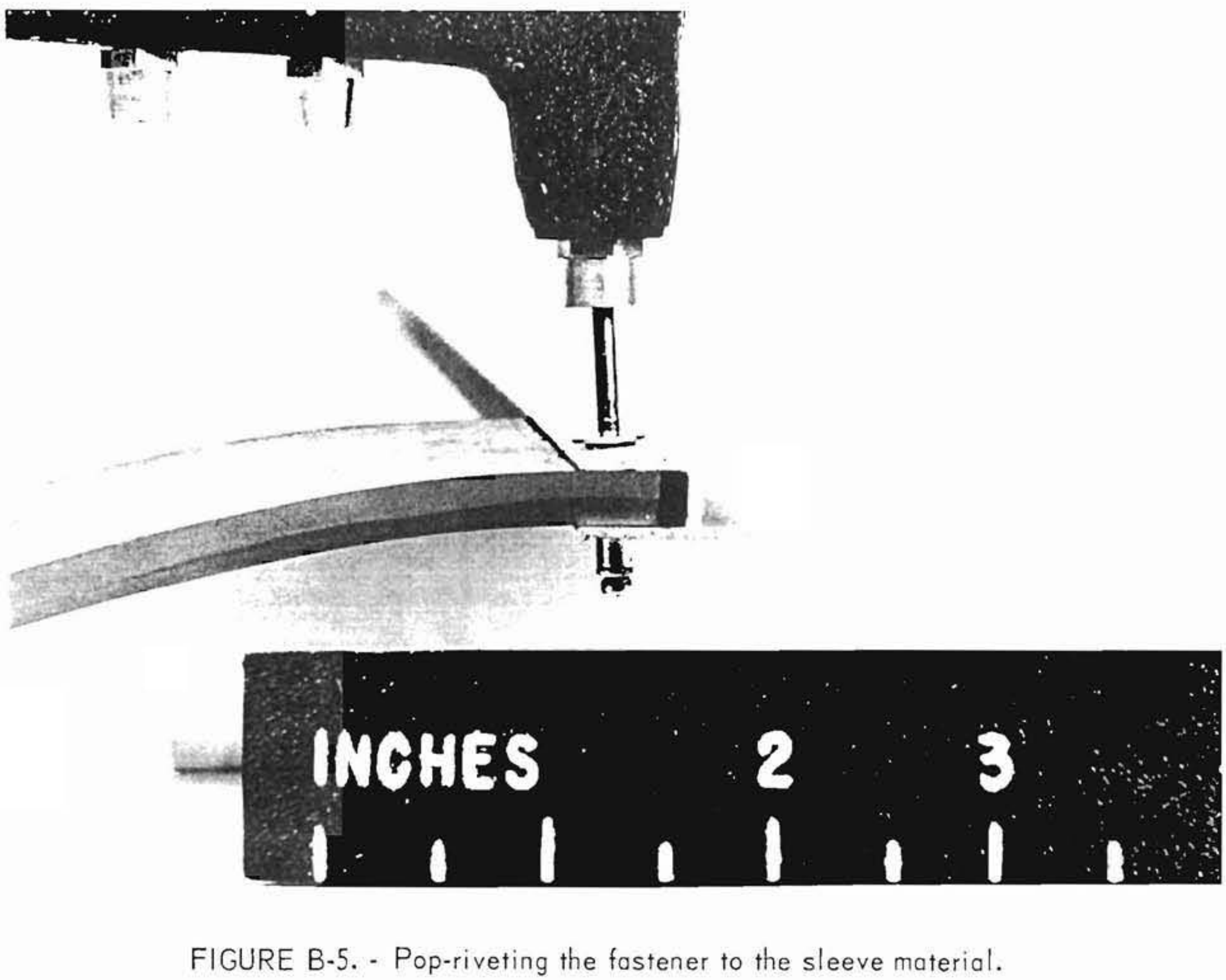

FIGURE B-5. - Pop-riveting the fastener to the sleeve material.

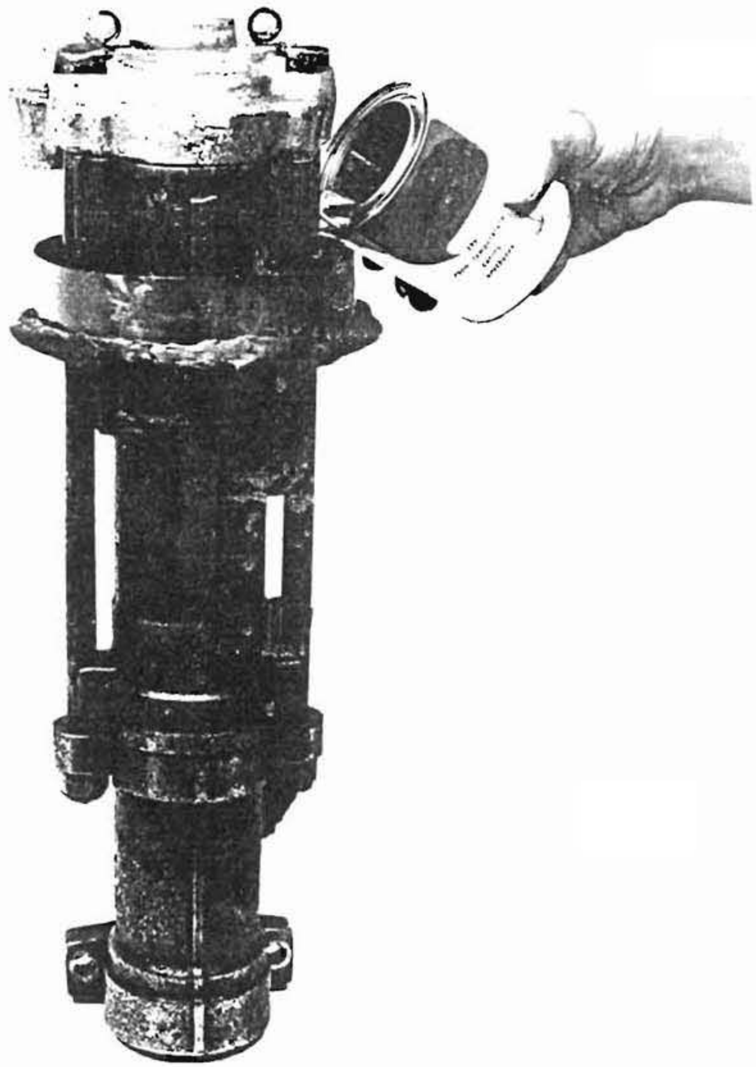

FIGURE B-6. - Method of forming caps to conform to the configuration of the drill body.

To fabricate the end caps, the drill was held in a vertical position, and a form of sheet metal and duct-seal was fitted around the drill body at appropriate positions at the proposed extremities of the cover (fig. B-6). The form should include a 1/4-inch edge at the outside of the cap to prevent slipping into the sleeve. This is evident in figures B-7 and B-8. Figure B-7 shows a rod pushing the end cap into the sleeve whereas figure B-8 displays the worth of the 1/4-inch edge or rim.

After the forms are placed around the drill body, the liquid-type number 80 Flexane urethane purchased from Devcon Corp. of Danvers, Mass--a liquid, room-temperature, curing material--was poured into the molds as shown in figure B-6. After the end caps had been formed, they were slit at the narrowest point to facilitate installation (fig. B-9). The caps were then bored with a cork borer as shown in figures B-10 and B-11. Into these bored holes were fit two aluminum tubes with 0.035-inch wall thickness and an inside diameter such that the total cross-sectional area at least equals the drills exhaust port area. In this case, the inside diameter of the tubes was about 1/2 inch. The length of the tubes should be about three-fourths of the length of the jacket. A split end cap with tubes installed is shown in figure B-12.

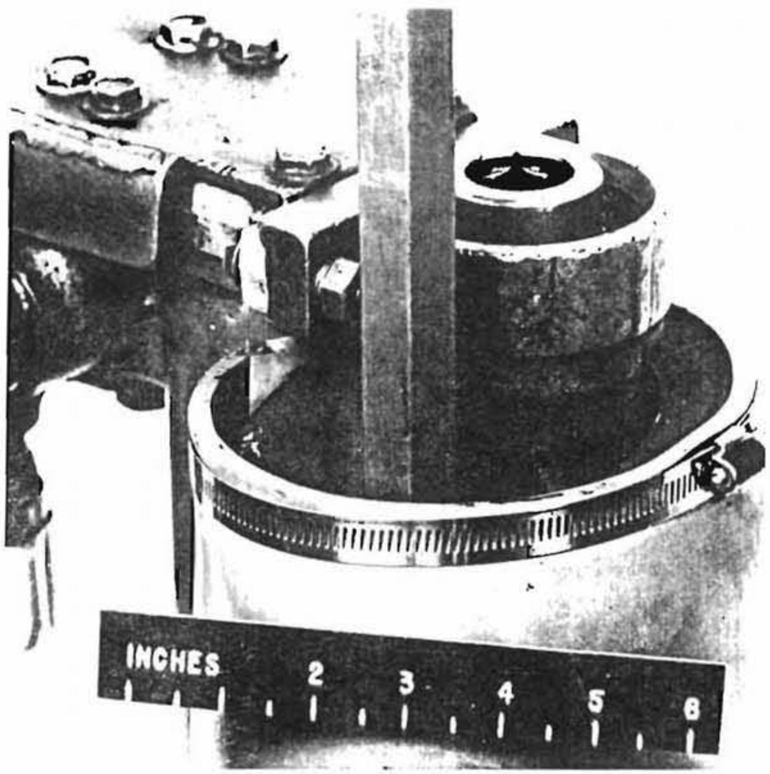

FIGURE B-7. - The possible result of an end cap without a cap flange.

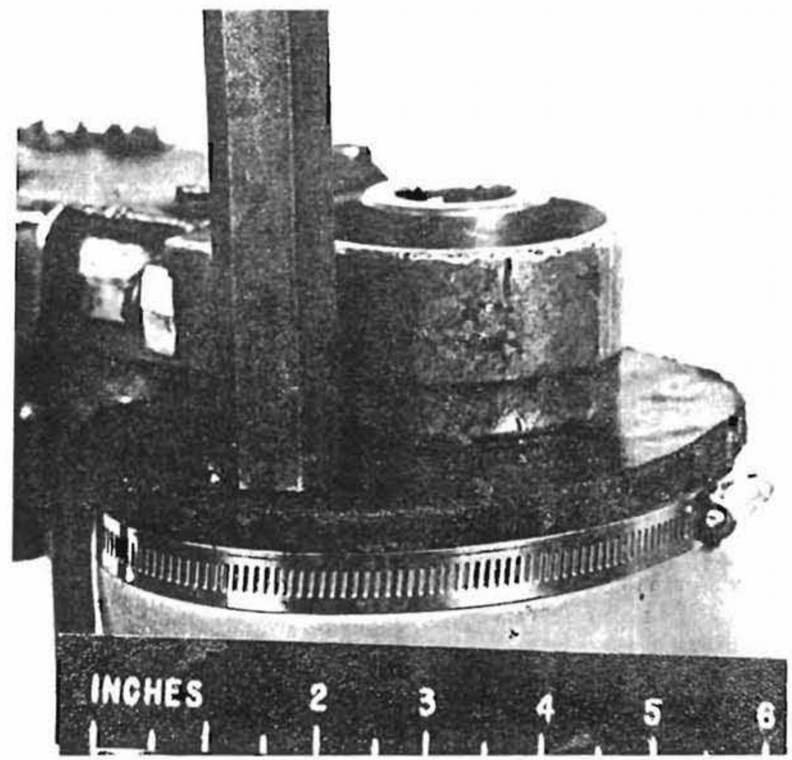

FIGURE B-8. - Showing the advantage of a flanged end cap.

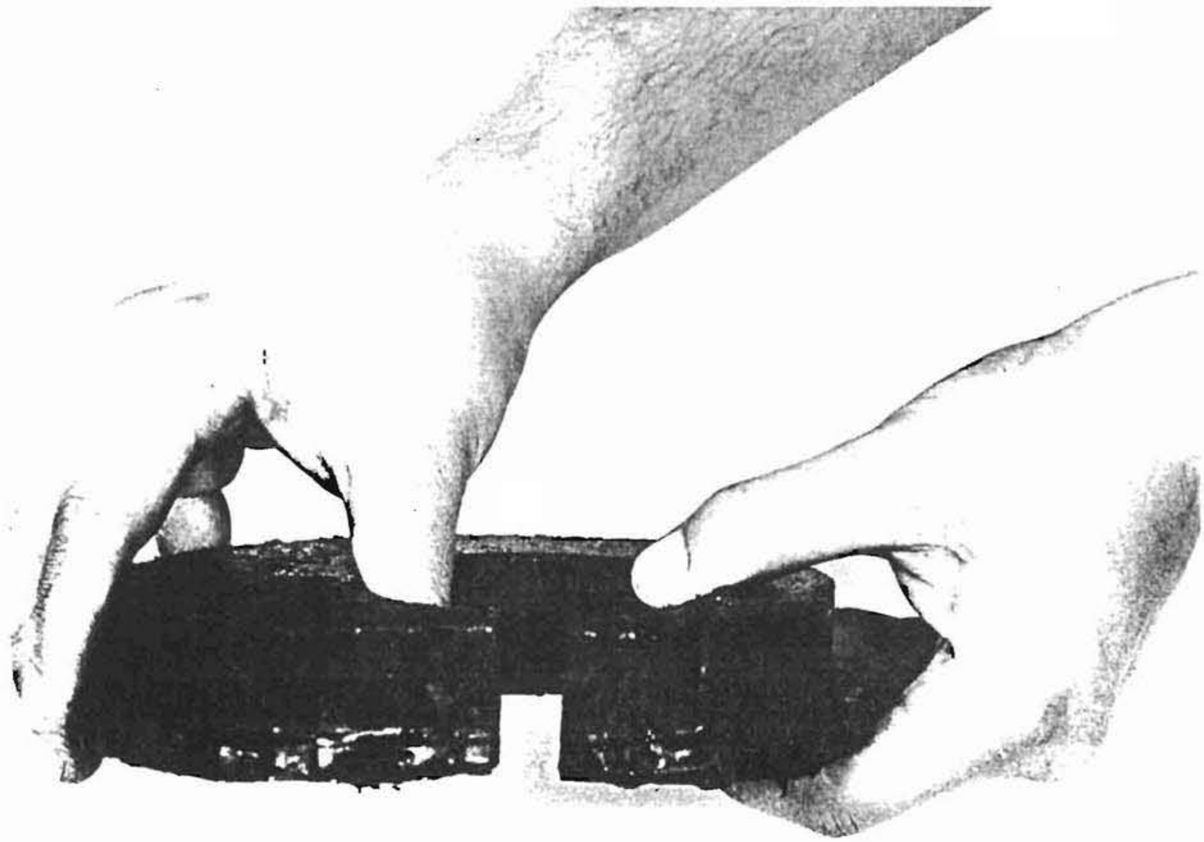

FIGURE B-9. - A split end cap to facilitate installation.

Various types of drills will require some innovation such as with the Ingersoll-Rand RP38E being described. For this drill, the feed leg control handle protrudes from the center of the drill body. A snug hole was cut in the jacket at the proper place as measured with care not to cause a leak of the exhaust gases. The dust collector tube will also be beneath the jacket. For this vent, a hole was bored in the end cap to permit an aluminum tube to be brought out. The tubing was easily connected inside with a hose joint.

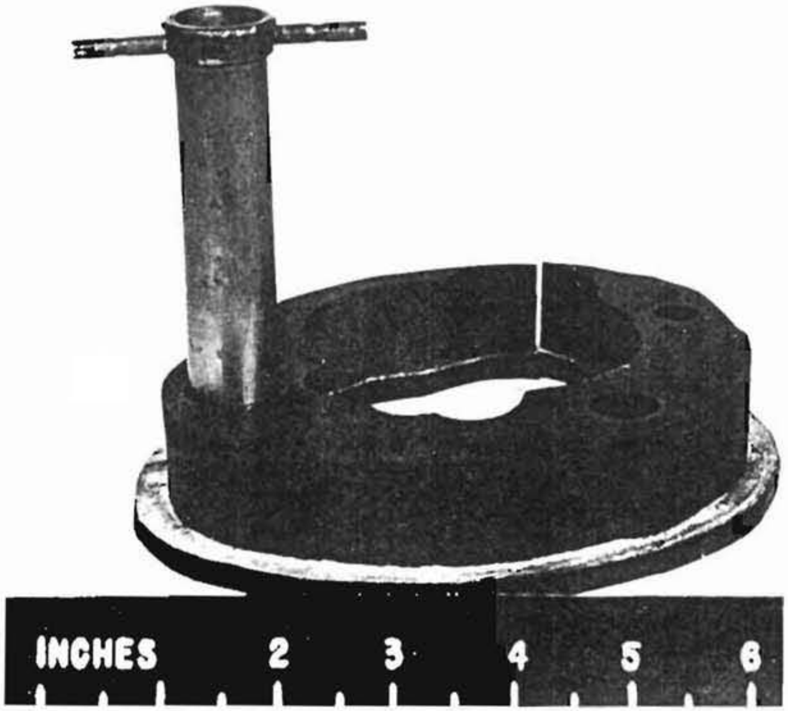

FIGURE B-10. - Cork bore and end cap.

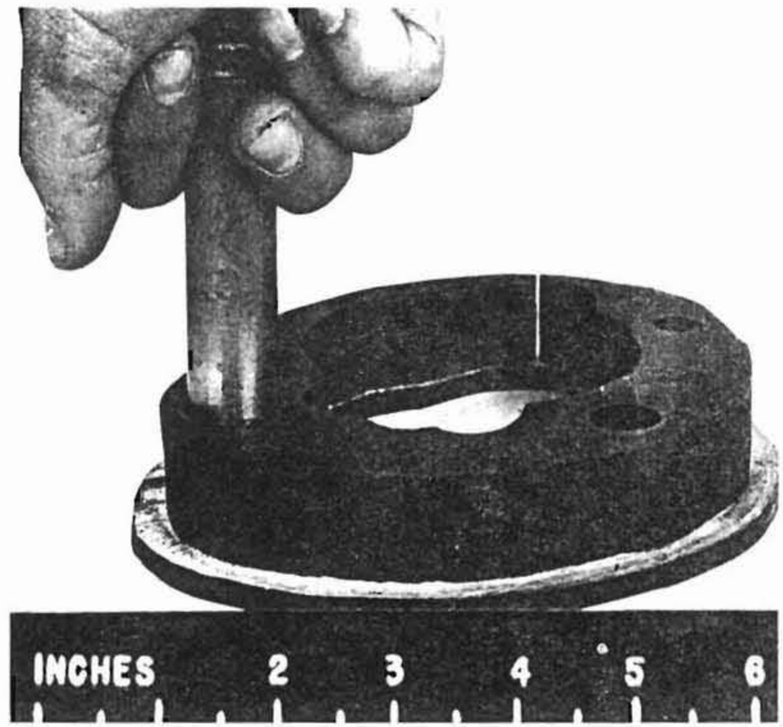

FIGURE B-11. - Boring an end cap for exhaust port tubes.

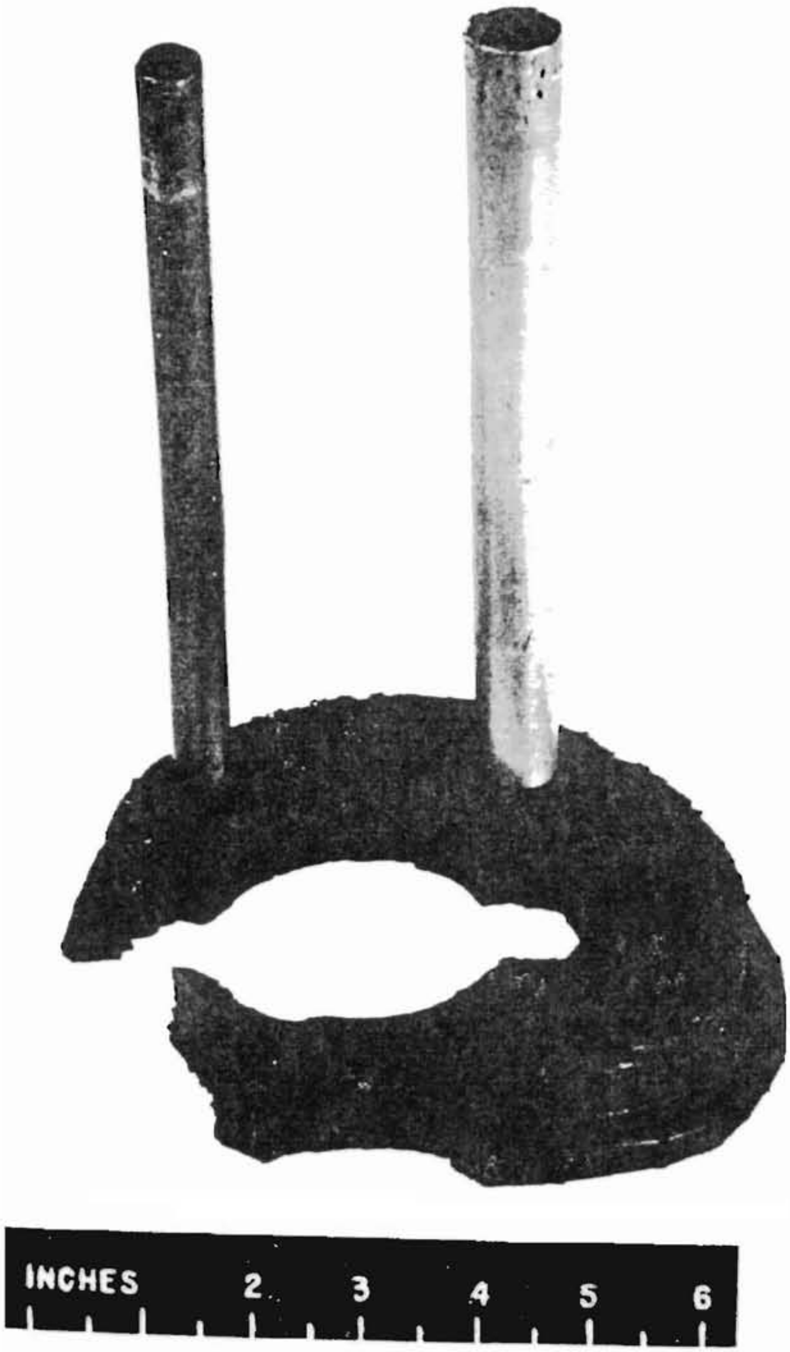

FIGURE B-12. - A split end cap with tubes installed.

Installing the Jacket and End Caps

The feed leg, handle, and connecting air hose were removed. The end caps were placed on the drill body, and the jacket cover was wrapped around the drill. The metal screws were used to join the ends of the cover. The drill at this point is shown in figure B-13. Large hose clamps were installed at each end of the jacket as shown in figure B-14. The feed leg handle and air hose were installed in figure B-15. Longer bolts were used to install the feed leg in order to extend the handle of the drill out and away from the jacket for sufficient room for handling. A photograph of the finished drill with the now unnecessary external muffler attached is shown in figure B-16.

Figure B-17 shows a Le Roi LSC-75 stoper drill, and figure B-18 shows a Le Roi Cleveland H23DR rack-mounted sinker drill, both of which have been modified with a jacket muffler similar to that of the described Ingersoll-Rand drill.

Drill Rod Noise Abatement

The rods used were 1 inch across the flats. Regardless of the rod length, the damper should be placed as near the chuck end as possible allowing sufficient space so that the damper is not hit by the chuck. Six to eight inches is sufficient length. Seamless steel tubing 1-3/8-inch OD by 0.049-inch wall was used. The elastomer or urethane used was the same as that for the end caps--number 80 Devcon

FIGURE B-13. - Fitting the sleeve to the end caps.

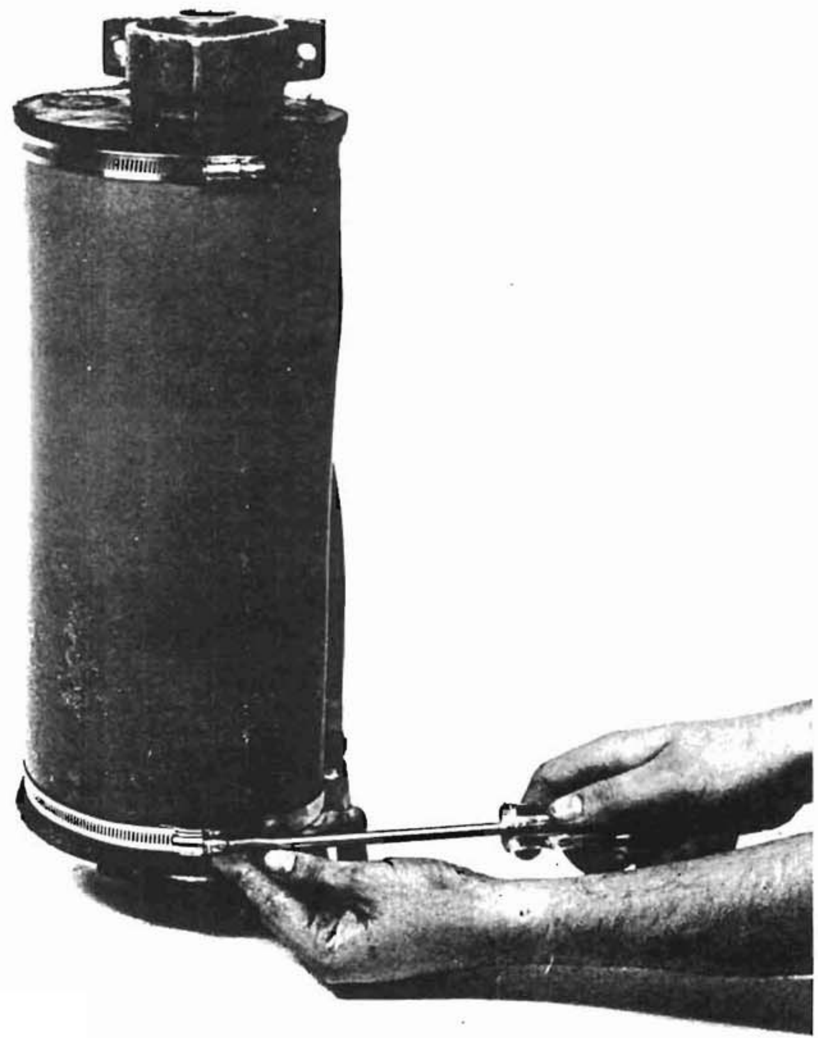

FIGURE B-14. - Installation of hose clamps to the jacket muffler.

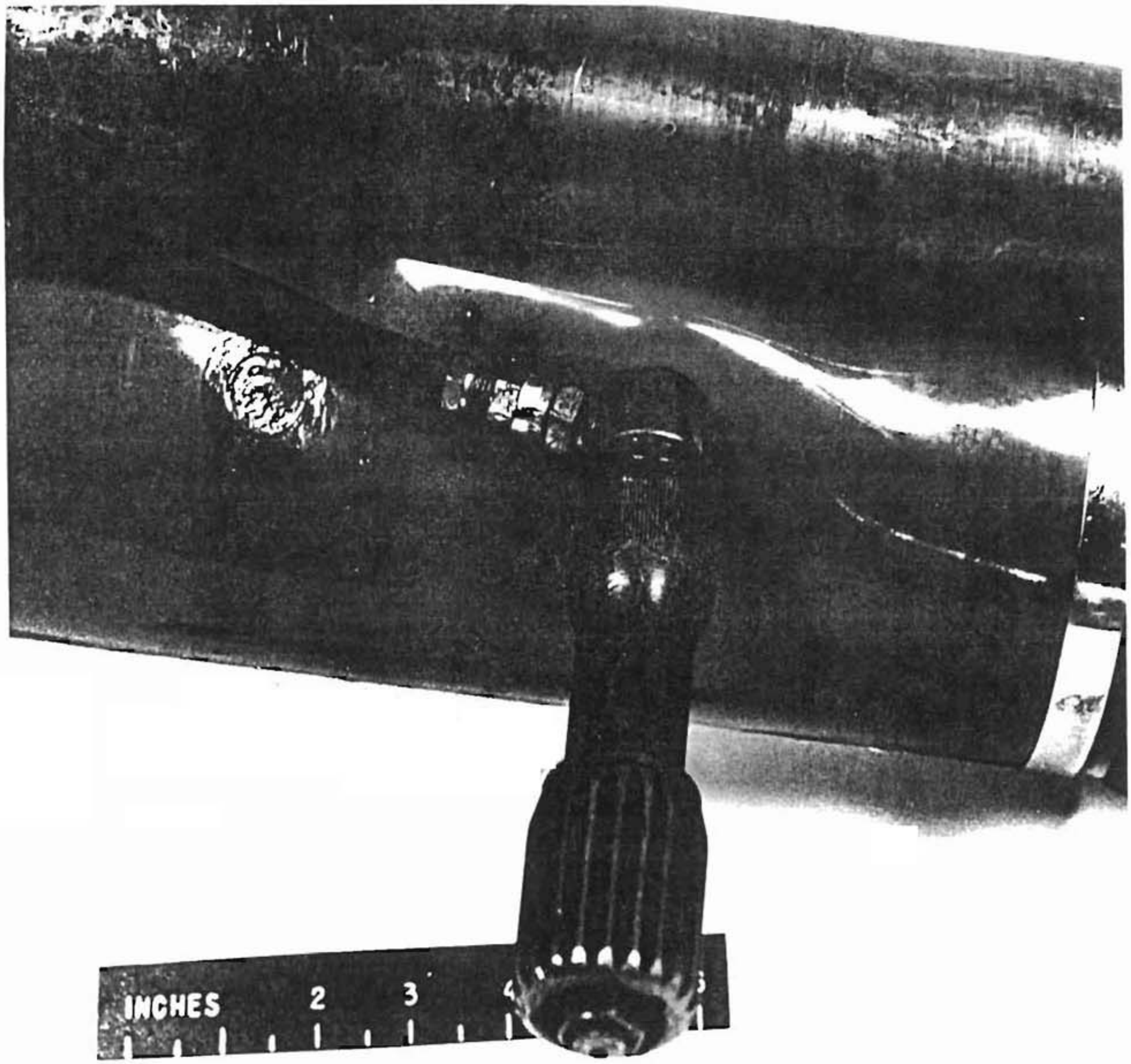

FIGURE B-15. - Feed leg handle protruding through the jacket.

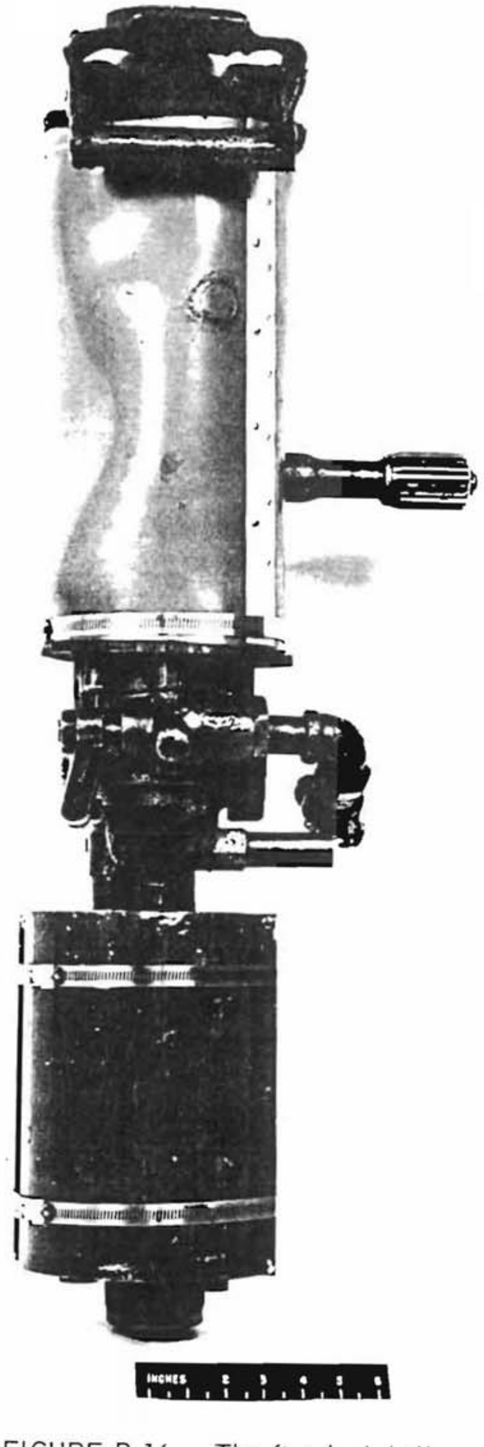

FIGURE B-16. - The finished drill with the now unnecessary external muffler.

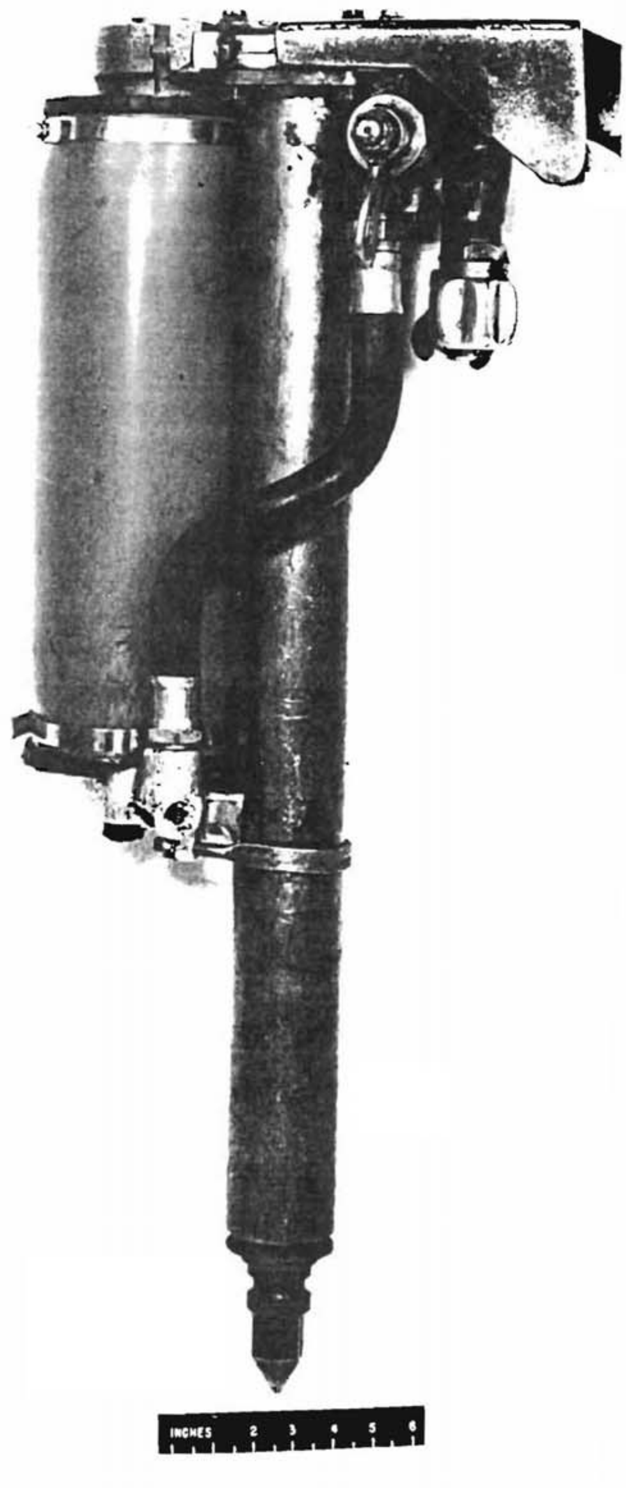

FIGURE B-17. - A Le Roi LSC-75 stoper drill fitted with a muffler jacket.

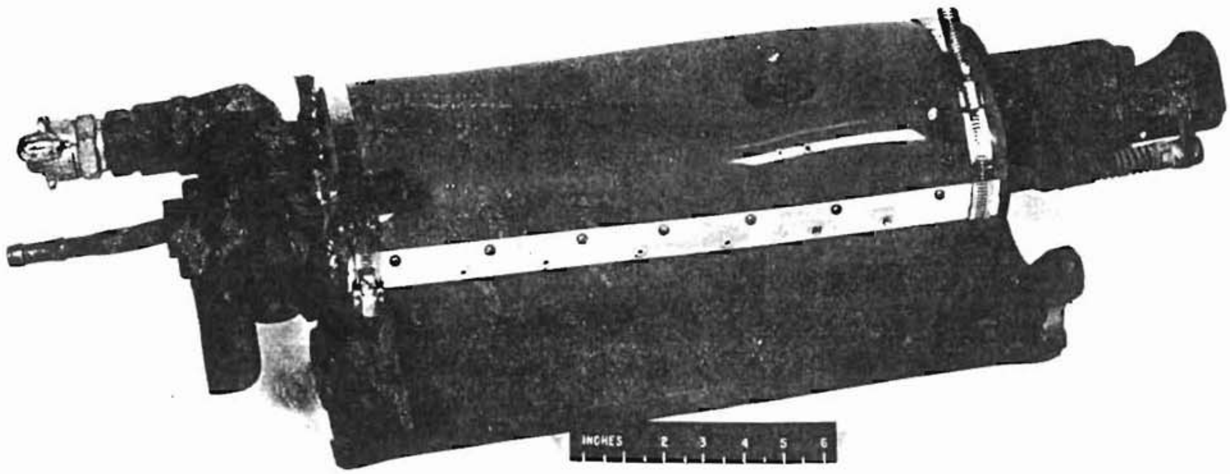

FIGURE B-18. - A Le Roi Cleveland H23DR rack-mounted sinker drill fitted with a muffler jacket.

Flexane. The inside of the tube and rod area must be perfectly clean for good adhesion. These areas were sandblasted to create good contact, but success has been achieved by cleaning with acetone as in figure B-19. If the rod used has a shoulder and a flared bit end, the tubing must be split with a hacksaw forced over the rod and, as in figure B-20, sprung together again in a vise. The seam may be spot-welded, but spot welding is not essential. The rod was then suspended vertically, and small spacers were forced in at each end of the tube to keep it concentric with the rod. Sealer such as duct-seal was used to close the bottom of the tube, and the liquid urethane Flexane was poured into the top (fig. B-12). It was necessary to make a small hole in the seal at the bottom to let out any air bubbles and insure that the tube was full of Flexane. A view of a bare rod with shoulders is shown in figure B-22, and an abated rod with constricted layer damping is shown in figure B-23.

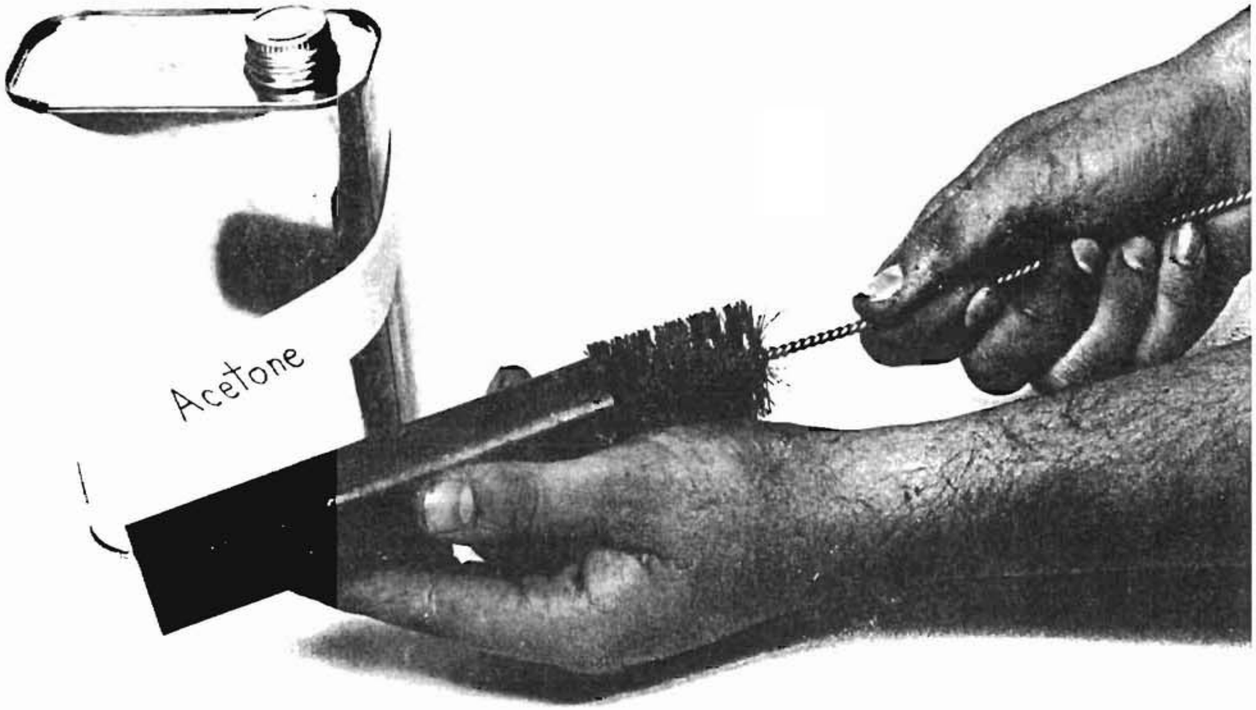

FIGURE B-19. - Cleaning the inside surface of a steel tube to insure good Flexane adhesion.

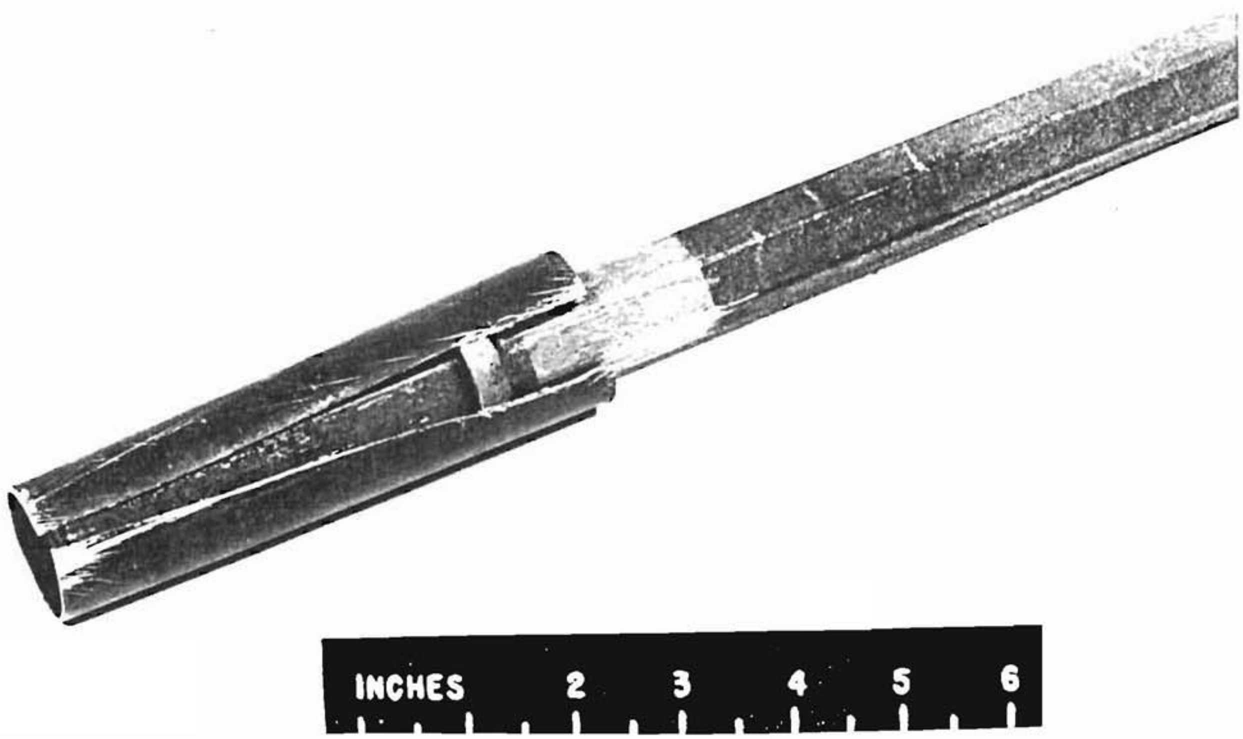

FIGURE B-20. - Installing a steel tube onto a shouldered drill rod.

FIGURE B-21. - Filling a tube with liquid Flexane.

FIGURE B-22. - An unabated rod with a shoulder.

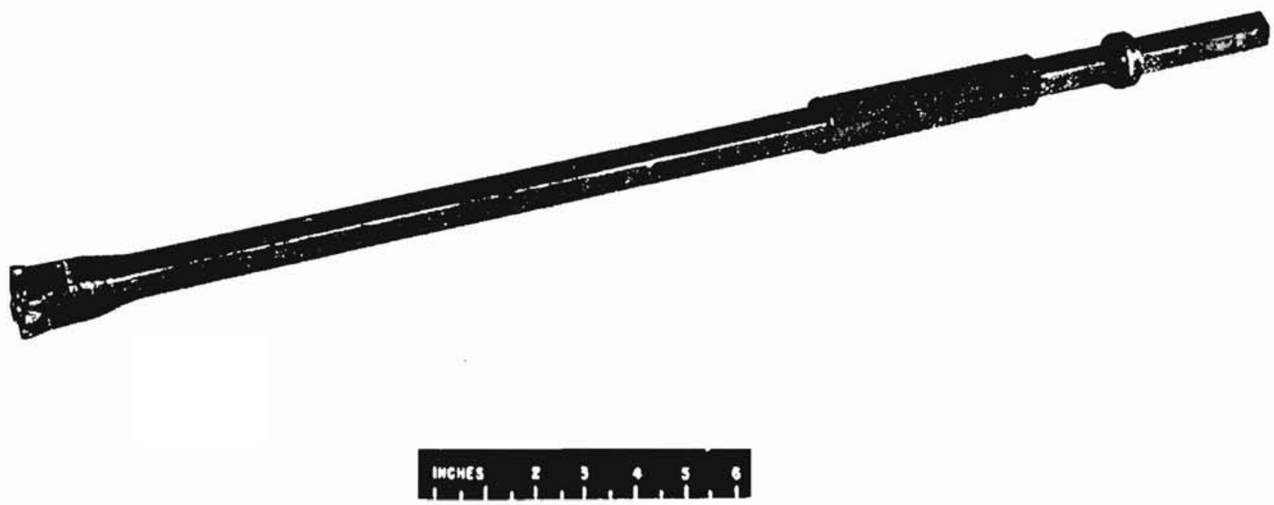

FIGURE B-23. - A shouldered drill rod with constricted layer damper installed.

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