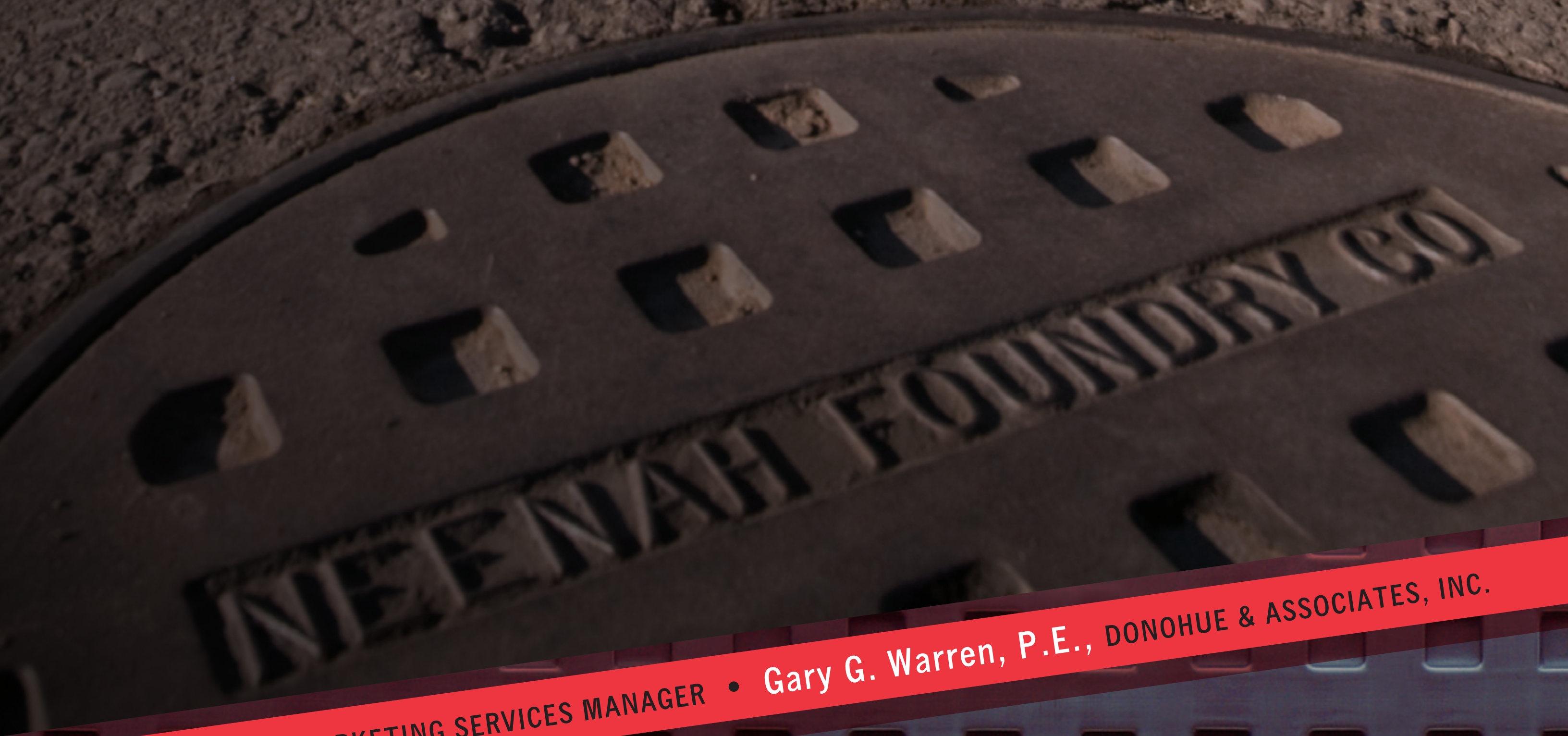
A REPORT ON INFLOW OF SURFACE WATER
Through Manhole Covers



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NEENAH FOUNDRY

UNITED STATES OF AMERICA MADE IN AMERICA

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INTRODUCTION

With the current awareness of the ecological ramifications of water pollution, much effort and money is being directed towards the cost of effective upgrading of wastewater treatment facilities and distribution systems throughout the nation. This upgrading not only deals with requirements for higher levels of treatment for daily wastewater flows at treatment facilities, but is also directed at the reduction and eventual elimination of in-system bypassing of wastewater. This bypassing is largely a result of the intrusion of surface runoff waters and/or groundwater into sewer systems during wet weather periods of the year.

To help relieve the financial burden of the system upgrading and rehabilitation, federal grants are available. Financing is available under the 1981 amendments to PL 97-117. Until 1985, Step 3 Projects will be funded at 75% — after that at 55%. Steps 1 and 2 are also eligible for funding at a rate based on the average cost of similar projects.

This joint report by Neenah Foundry Co. and staff members of American Consulting Services of Minneapolis, Minn. is an outgrowth of investigations conducted as part of one particular phase of the construction grants program, namely the Sewer System Evaluation Survey (SSES). As defined in the federal government's Title 40 Rules and Regulations, a Sewer System Evaluation Survey . . . "consists of a systematic examination of the sewer system to determine the specific location, estimated flow rate, method of rehabilitation and cost of rehabilitation versus cost of transportation and treatment for each defined course of infiltration/inflow".[1]

PURPOSE

With the investigations conducted in the field according to the SSES Program, one of the most common and costly sources of inflow identified in most of today's sewer systems, is manhole lids subject to surface runoff inflow. (See Figure 1 and other examples, Appendix B). There has been a general absence of information as to how much surface water could inflow into a system through manhole lids. It was this need that provided the stimulus for this report with the hope that some simple, effective method of rehabilitation could be designed.

[1] Infiltration/Inflow — See Definitions, Appendix A.

This report, in particular, investigates:

(1) Quantities of surface runoff which enter the sewer system through different sized manhole lids.

(2) How surface runoff, manhole lid bearing surface, and pickhole and vent hole area affect the quantity of inflow through these lids.

(3) An effective, relatively inexpensive, alternative for the elimination of this source of inflow into the sewer system.

It is hoped that the information contained in this report will help to enlighten municipalities, their consultants and respective state or federal agencies to the magnitude of this problem and to the alternative available for its solution.

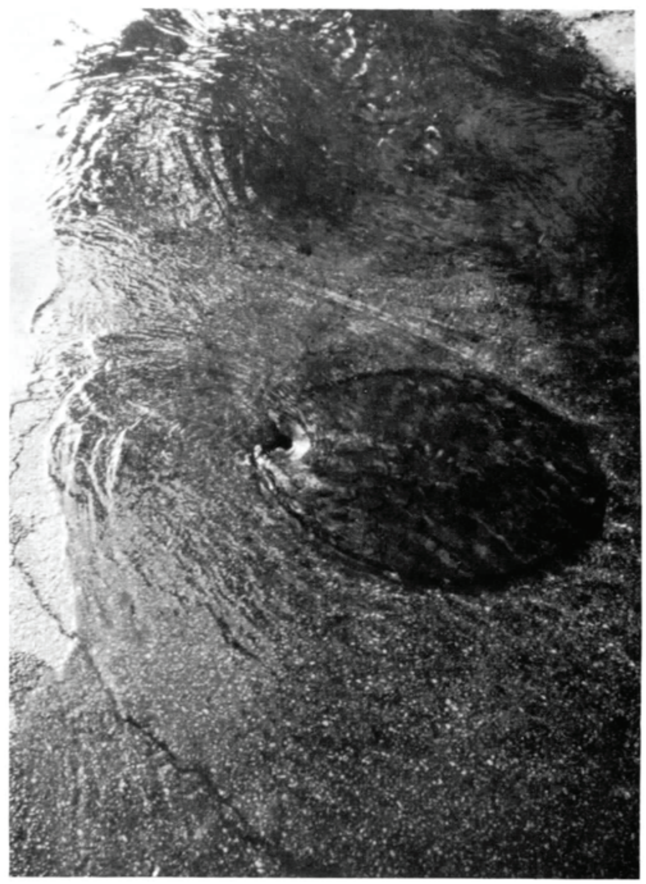


Figure 1
Inflow Through Manhole Lid

APPARATUS

To conduct the tests a large cylindrical flooding tank was constructed. (See Figure 2). The tank had an inside diameter of 39½″, was 15″ deep and was equipped with a 3″ diameter outlet pipe which protruded from the bottom center of the tank. A rubber coated wooden plug was used as the stopper for this outlet. The tank was supported about 3 feet above the floor by four legs to accommodate an 18″ x 36″ x 15″ deep receiving tank. To facilitate measurement of the inflow water collected in the tank after each trial, the receiving tank was equipped with casters which allowed it to be rolled out from under the flooding tank.

The manhole frames were bolted to the bottom of the test tank, using a flat rubber gasket as a seal. This provided a watertight joint between the tank and manhole frame. Water would then be introduced into the flooding tank by hose, filling it to the desired head.

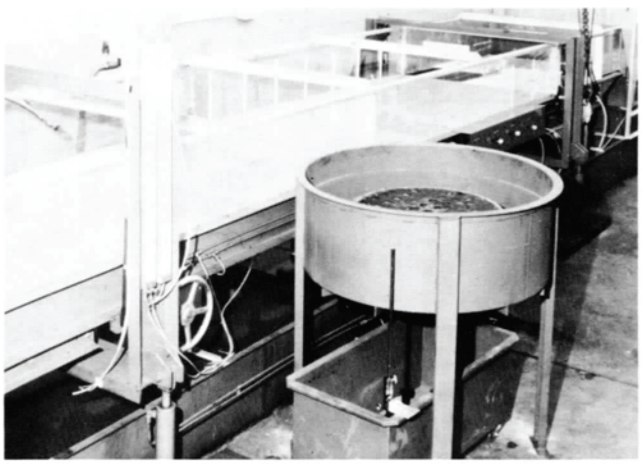


Figure 2
Flooding Tank

PROCEDURES

With the receiving tank empty and the outlet plugged, the test could begin at the time water began to flow through the top of the manhole cover. Duration of the test was one minute by stop watch and the water was allowed to flow into the receiving tank below. After one minute the outlet was plugged so no additional water could enter the receiving tank. The water collected in the receiving tank was then measured with a point gauge and recorded as the amount of inflow that the particular manhole lid would allow to enter during the one minute time period.

There are basically two locations in manhole lids through which surface runnoff can enter the manhole lid. One is by direct passage through open pick and vent holes, and the other is by seepage through the manhole lid and frame contact (bearing) surface along the perimeter of the manhole frame and lid. All of these sources would be affected directly by increased water head. In addition, the bearing surface itself will permit varying amounts of inflow depending on the quality of the seating surfaces and whether that surface is ground or commercially machined.

In order to more closely evaluate what part of the total manhole inflow can be associated with the bearing surface and vent and pickhole areas, the testing was set up to test each source separately.

To test for bearing surface inflow, solid manhole covers containing concealed pickholes were used. Five different sized manhole cover assemblies detailed in Appendix C and ranging in size from 22″ to 26″ in diameter were tested, first with a ground bearing surface and then these same sizes were again tested with a machined finish bearing surface. To overcome the variations expected from one set of castings to another, a total of 136 different casting sets were randomly selected from the Neenah Foundry stock. Over 2000 individual tests were conducted and averaged into 441 categorized separate data points, reproduced in Appendix D of this report.

To test for pickhole and venthole inflow, manhole lids were sealed to the frames to make watertight bearing surfaces. Each lid contained one hole either ¾″, 1″, 1¼″, 1½″ or 2″ in diameter. Ten trials were run for each hole diameter to determine average values for plotting as shown in Appendix E.

Three water head conditions were simulated for each lid to reflect basic runoff situations for both bearing surface and vent and pick hole tests.

They are:

Test 1: Splashing water on lid simulating steady rainfall with no ponding.

Test 2: Water on cover allowed to accumulate to ⅛″ head.

Test 3: Runoff simulation allowed to pond to a 1″ head.

No attempt was made to introduce dirt, debris, sand or silt into the clear water or manhole lid and frame bearing surfaces and holes.

RESULTS

A. Bearing Surface Inflow

The results of the bearing surface inflow tests are summarized in the following tables 1 and 2, and are graphically presented in figures 3 through 7.

Table 1
Non-Machined Bearing Surface Inflow

Manhole Type	Diameter Inches	Test 1		Test 2		Test 3	
		Avg. GPM	Std. Dev.	Avg. GPM	Std. Dev.	Avg. GPM	Std. Dev.
R-1090	22	3.88	1.10	9.81	2.12	15.99	3.74
R-1040	23	2.20	1:00	7.76	4.15	14.80	6.02
R-1670	24	3.97	1.21	12.08	2.34	17.34	3.88
R-1760	25	6.26	1.53	12.89	3.11	18.57	4.06
R-1642	26	3.65	1.14	10.62	3.79	17.29	5.57
Avg.		3.99		10.63		16.80	

Table 2
Machined Bearing Surface Inflow

Manhole Type	Diameter Inches	Test 1		Test 2		Test 3	
		Avg. GPM	Std. Dev.	Avg. GPM	Std. Dev.	Avg. GPM	Std. Dev.
R-1090	22	.99	.37	1.27	.43	1.87	.56
R-1040	23	.82	.30	1.60	.99	2.27	1.67
R-1670	24	.93	.42	2.00	.54	2.81	.84
R-1760	25	1.43	.36	2.29	.70	3.23	1.02
R-1642	26	1.14	.50	1.87	.79	2.52	.96
Avg.		1.06		1.81		2.54	

The effect of machined bearing surfaces on the reduction of bearing surface inflow is very graphically pictured in figures 3 through 7. As the standard deviation computations reveal, individual manhole frame and lid combinations within the same manhole type and test condition can differ significantly in the amount of inflow they will allow.

B. Venthole and Pickhole Inflow

Figure 8, page 9 portrays the results of the pickhole/venthole tests conducted on ¾″, 1″, 1¼″, 1½″ and 2″ diameter pick/vent holes. As might be anticipated, the results for all three of the test conditions closely approximate a straight line relationship between water head, hole area, and inflow received. The slopes of these curves are as follows:

Test	Inflow (GPM/in.^{2})
1	0.25
2	1.00
3	4.94

FIGURE 3

R1090 WITH CONCEALED PICK HOLES, LID DIAMETER 22"
INFLOW THROUGH BEARING SURFACES ONLY

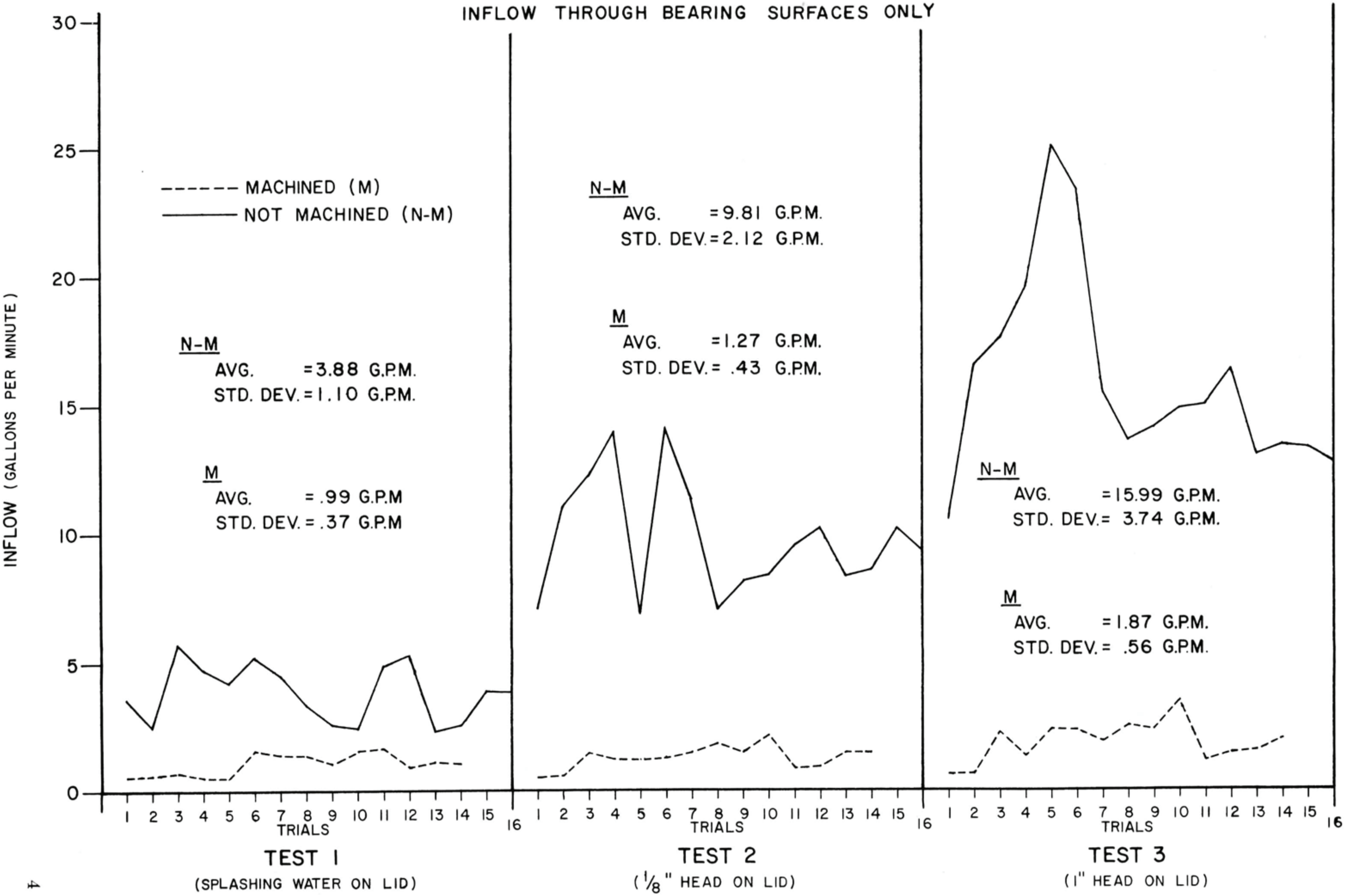


FIGURE 4

R 1040 WITH CONCEALED PICK HOLES, LID DIAMETER 23"

INFLOW THROUGH BEARING SURFACES ONLY

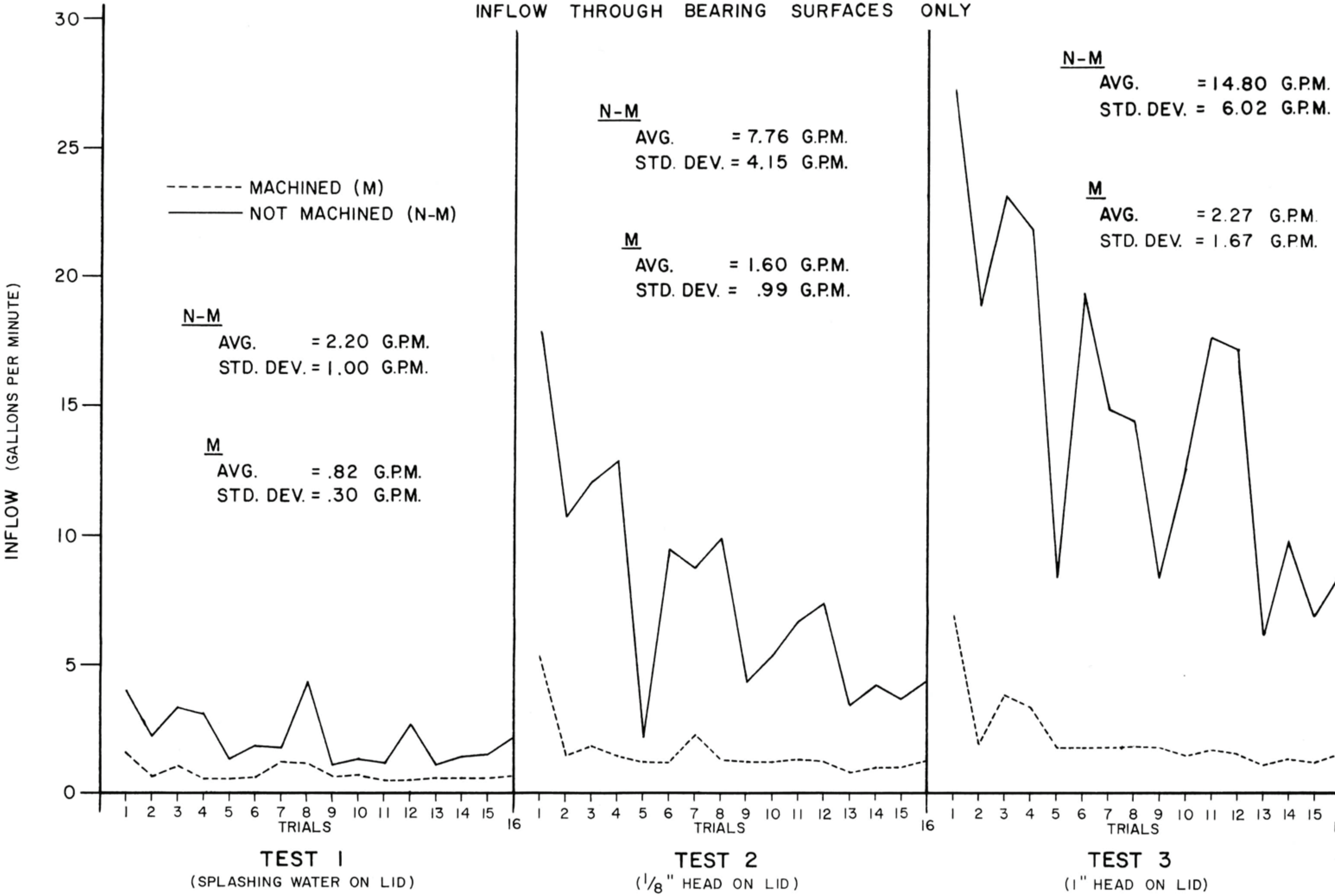


FIGURE 5

R 1670 WITH CONCEALED PICK HOLES, LID DIAMETER 24"

INFLOW THROUGH BEARING SURFACES ONLY

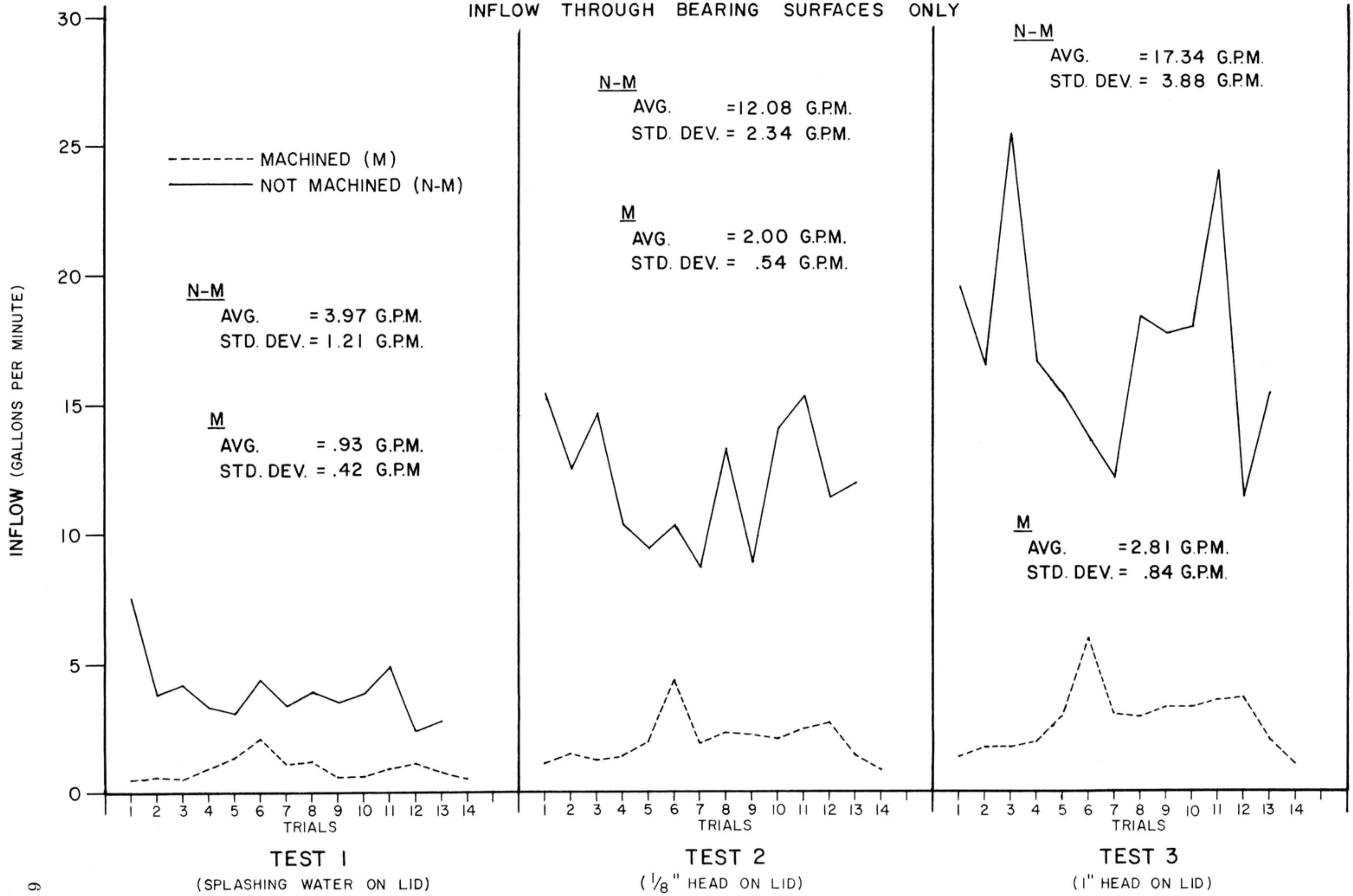


FIGURE 6

R 1760 WITH CONCEALED PICK HOLES, LID DIAMETER 25"

INFLOW THROUGH BEARING SURFACES ONLY

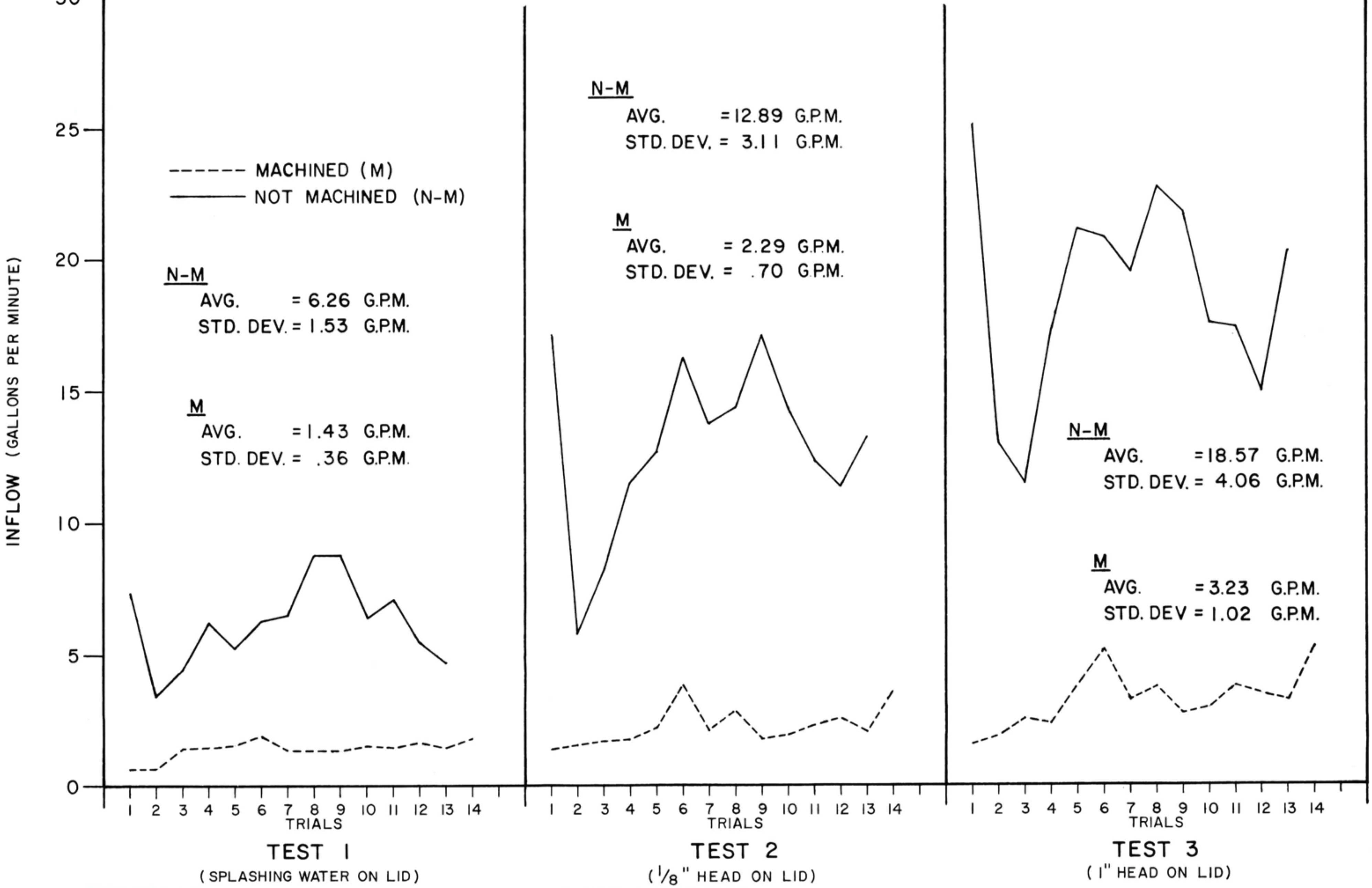


FIGURE 7

R 1642 WITH CONCEALED PICK HOLES, LID DIAMETER 26"

INFLOW THROUGH BEARING SURFACES ONLY

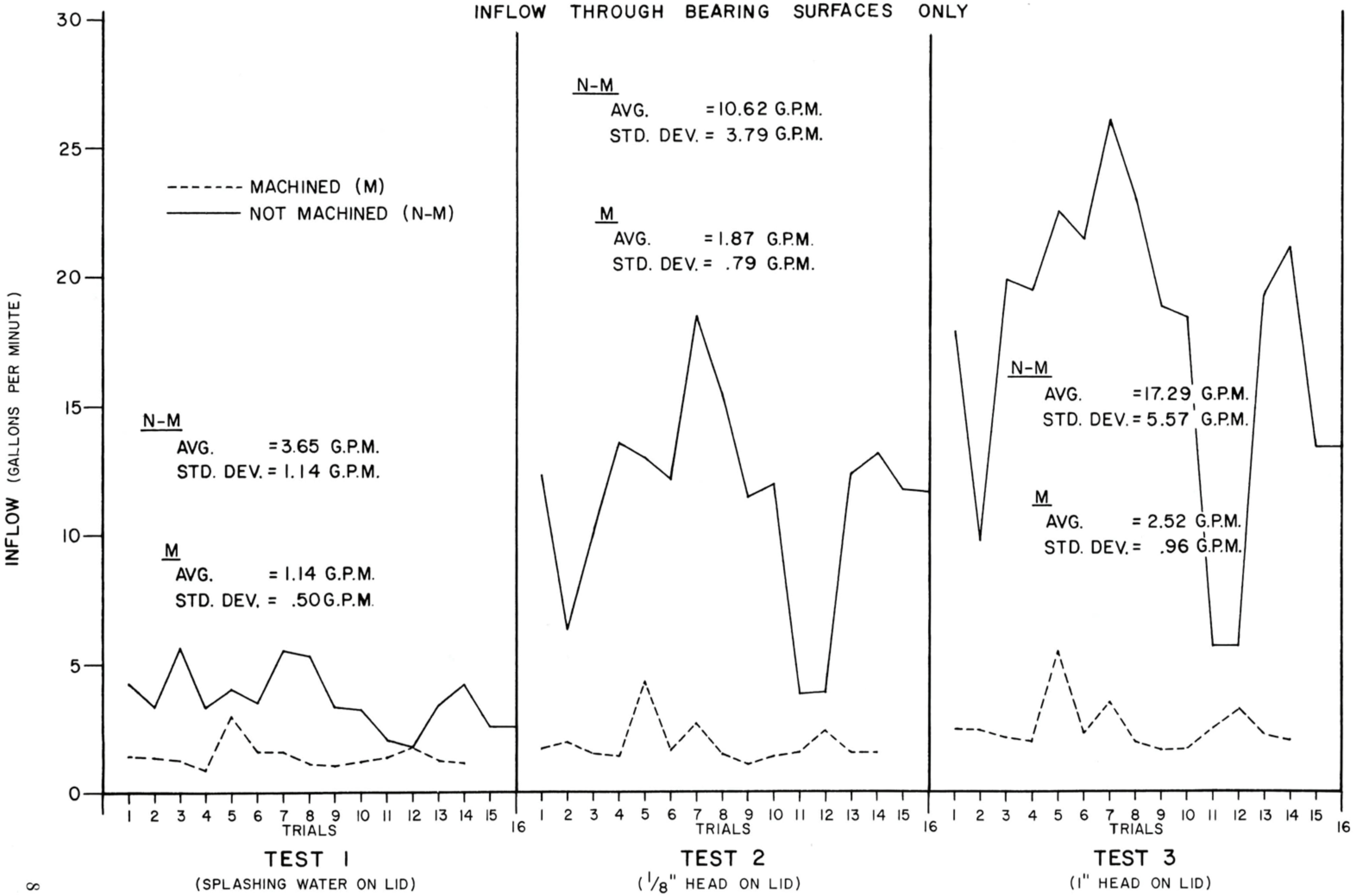
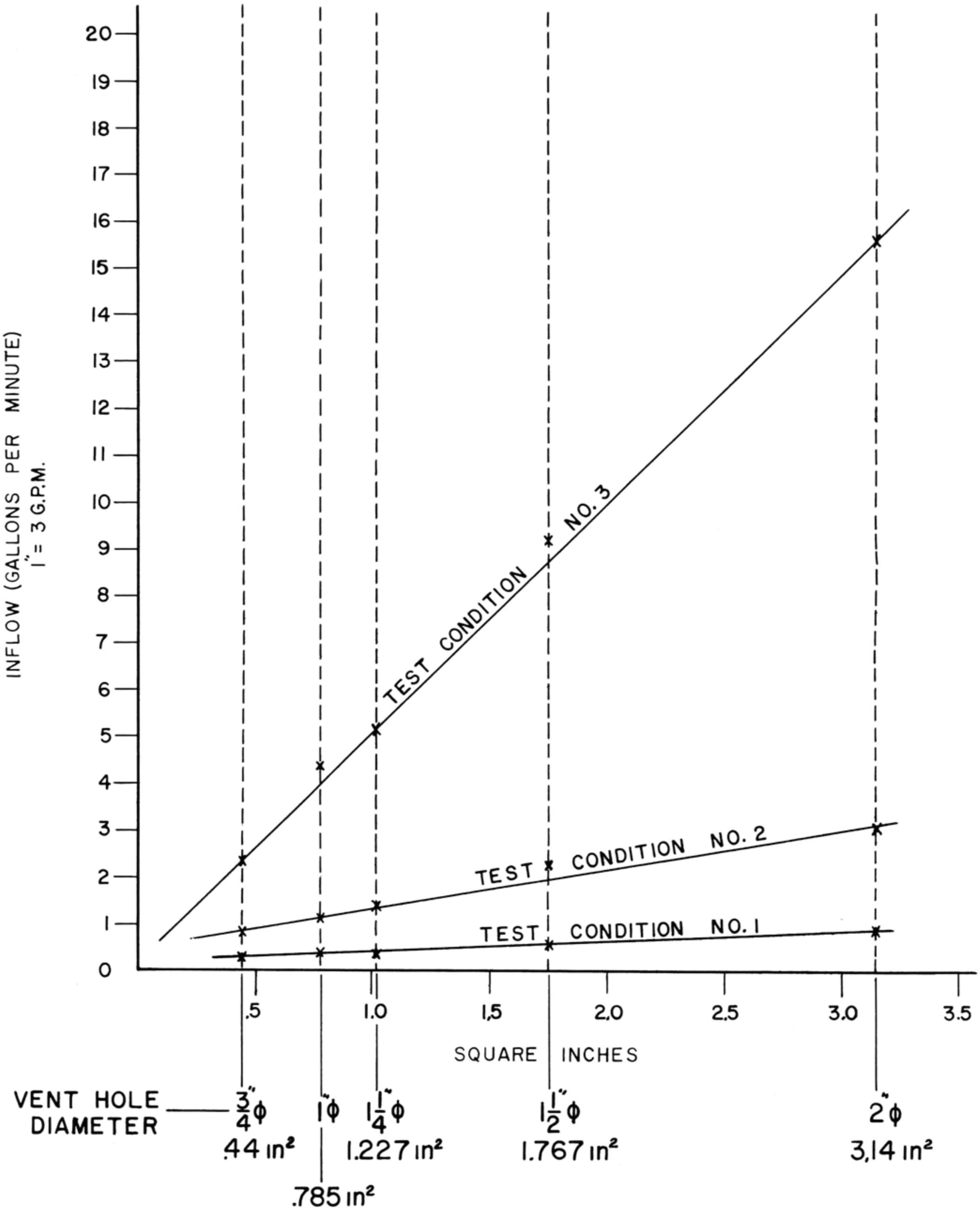


FIGURE 8

VENT HOLE / PICK HOLE INFLOW



CONCLUSIONS

It has been demonstrated as a result of this study that significant amounts of surface runoff water can enter a sanitary sewer system through vent holes, open pickholes and the apparently invisible space which exists at the contact (bearing) surfaces between manhole frames and lids. The amount of inflow will vary depending on the runoff (waterhead), manhole cover circumference, the degree of machining of the bearing surfaces, and on the amount of open area provided by pickholes and ventholes.

The results from the machined bearing surface tests indicate a proper fit between frame and lid is important for reducing inflow. This leads one to conclude that extra care should be taken by maintenance personnel to ensure that bearing surfaces be given a thorough dusting to remove any foreign material which would open the joints between manhole frame and lid and allow inflow.

The main criteria for determining if a manhole lid is a significant contributor to the inflow problem of the community, should be whether or not the manhole is subject to surface runoff and not simply how many holes it has in its cover. This is obviously important for two reasons.

1. Without water reaching the manhole, there would be no inflow.

And,

2. As the bearing surface tests have revealed, even manholes without any holes can allow significant amounts of inflow to enter through the bearing surface alone.

It is felt that for those systems in which inflow is a significant problem, manholes located in run off areas should be one of the first areas of the system to be investigated for the identification of inflow sources cost-effective for removal from the system. Neenah Foundry Company has developed a new, "Self-Sealing" replacement lid containing a simple, built-in gasket sealing system and concealed pickholes. This lid, subjected to the tests as described in this report, is virtually watertight. (Figure No. 9). Providing the existing manhole frame is in serviceable condition, these "Self-Sealing" lids can be manufactured to fit any frame at a very minimal expense. Neenah Foundry's brochure entitled "Self-Sealing Manhole Covers," available on request, describes this new product.

No attempt has been made to introduce debris such as sand, leaves, paper, gravel, etc. into either the test water or manhole frames and lids, since it would be virtually impossible to set up test standards for these variables. It is felt that this material could just as well seal the inflow source or worsen it by expanding the bearing surface gap. A point to consider is that a properly maintained system would have each manhole inspected and entered for cleaning purposes periodically throughout the year which would tend to maintain the manhole lids in a state more similar to the test data conditions.

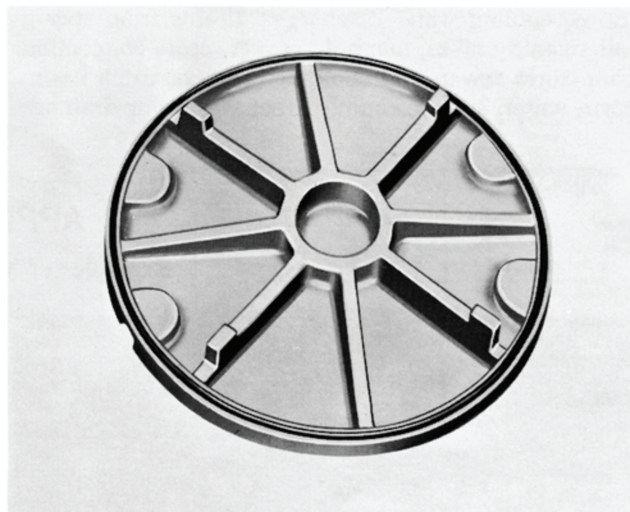


Figure 9. Neenah Self-Sealing Lid
Pat. No. 4,101,236

RECOMMENDATIONS

There are many ways to use the data in this report so as to arrive at the quantity of inflow a community's manholes might allow. Although the empirical data from the testing is quite extensive, one must be cautious in its use because of recognized variations in field conditions. What this report has hopefully done, is to confirm for the reader, that even manholes located in marginal runoff areas can experience significant amounts of inflow through the lids.

The key recommendation then is to first **locate those manholes subject to runoff** and then use this report data or a version thereof to evaluate the inflow contribution to the system. Those lids which are identified as significant inflow contributors can then be economically and effectively replaced with the Neenah "Self-Sealing" type lids.

APPENDIX A

DEFINITIONS*

Infiltration —

The water entering a sewer system and service connections from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections or manhole walls. Infiltration does not include, and is distinguished from, inflow.

Inflow —

The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, **manhole covers**, cross connections from storm sewers and combined sewers, catch basins, storm water, surface runoff, street washes or drainage. Inflow does not include, and is distinguished from, infiltration.

Infiltration/Inflow —

The total quantity of water from both infiltration and inflow without distinguishing the source.

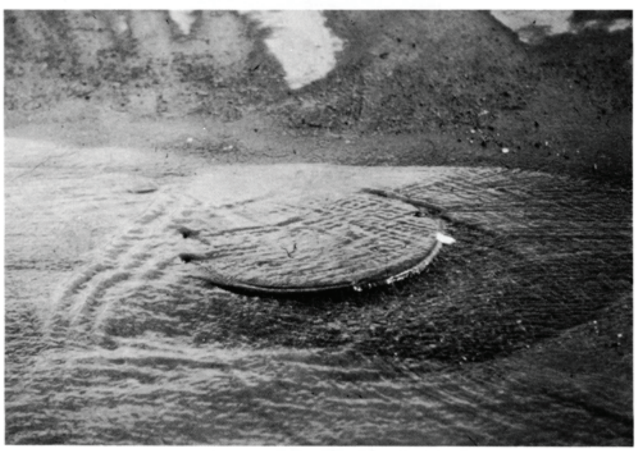
Excessive Infiltration/Inflow —

The quantities of infiltration/inflow which can be economically eliminated from a sewer system by rehabilitation, as determined by a cost-effectiveness analysis that compares the costs for transportation and treatment of the infiltration/inflow, subject to the provisions in Section 35.927.

*As defined in the Title 40 Rules and Regulations and published in the Federal Register, Section 35.905, Volume 39, Number 29, February 11, 1974.

APPENDIX B

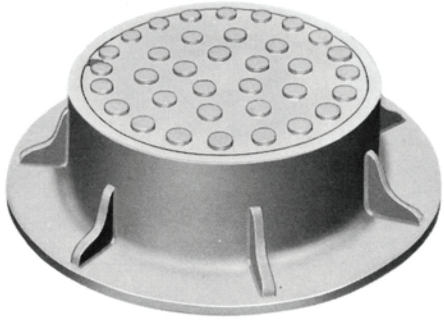
Examples of Manhole Lid Inflow



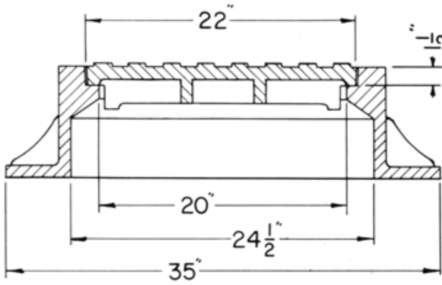
Copies of slides showing actual manhole lid inflow.

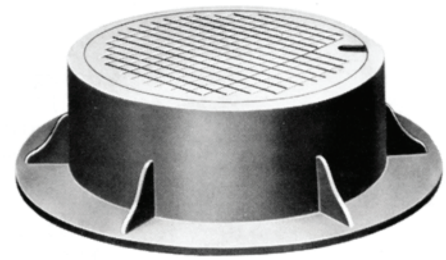
APPENDIX C

ILLUSTRATIONS AND DETAILS OF MANHOLE FRAMES AND LIDS TESTED WITH MACHINED AND NON-MACHINED BEARING SURFACES

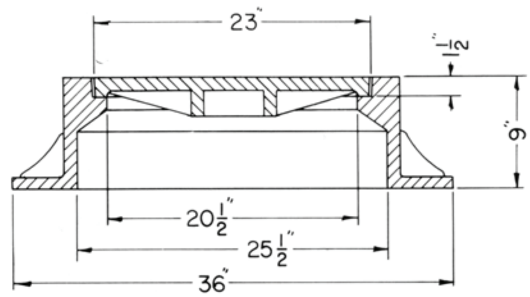


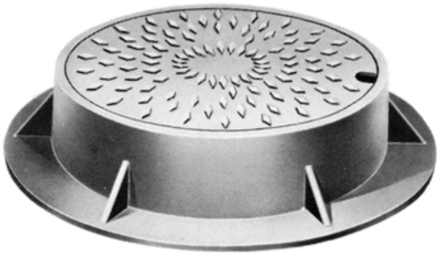
R-1090



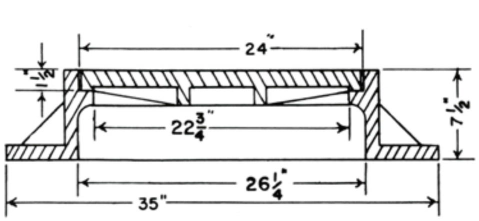


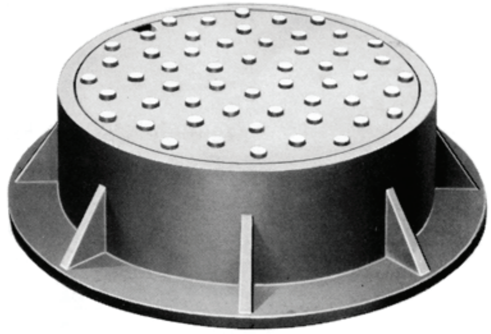
R-1040



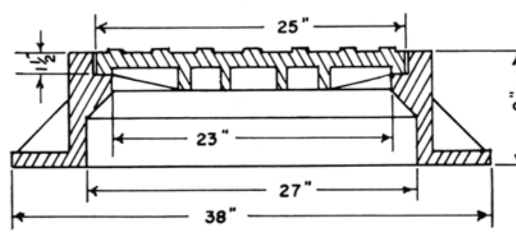


R-1670

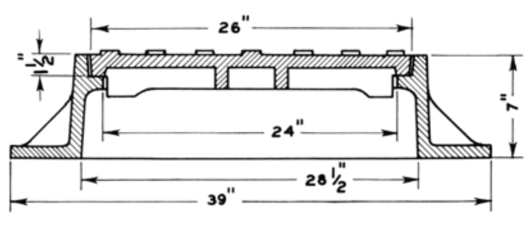




R-1760



R-1642



APPENDIX D

Tables Showing Inflow in GPM through Bearing Surfaces Only

(Data Points are Averages of Over 2000 Separate Tests)

High Values are Bold Face
Low Values are Bold Face Italic
– No Test

Manhole Casting Size — R-1090, Lid Circumference 69.1″

	Ground Bearing (Not Machined)			Machined Bearing		
Trial	**Test 1**	**Test 2**	**Test 3**	**Test 1**	**Test 2**	**Test 3**
1	3.67	7.11	***10.60***	***.47***	***.47***	***.64***
2	2.52	11.03	16.69	.60	.64	.67
3	**5.74**	12.30	17.70	.75	1.46	2.20
4	4.74	14.00	19.96	.59	1.14	1.29
5	4.18	***6.89***	**25.04**	.59	1.11	2.38
6	5.16	**14.20**	23.31	**1.61**	1.22	2.31
7	4.59	11.35	15.53	1.41	1.51	1.96
8	3.39	7.09	13.72	1.42	1.88	2.53
9	2.67	8.13	14.17	1.02	1.49	2.31
10	2.45	8.47	14.96	1.58	**2.10**	**3.59**
11	4.93	9.52	15.04	.77	.91	1.11
12	5.33	10.20	16.45	.94	.99	1.54
13	***2.30***	8.38	13.06	1.09	1.44	1.61
14	2.62	8.77	13.53	1.02	1.44	2.00
15	3.94	10.13	13.42	–	–	–
16	3.91	9.41	12.86	–	–	–

Manhole Casting Size — R-1040, Lid Circumference 72.3″

1	4.09	**17.95**	**27.34**	**1.68**	**5.33**	**7.95**
2	2.24	10.81	18.96	.70	1.54	1.98
3	3.33	12.18	23.25	1.04	1.91	3.87
4	3.10	12.96	21.92	.56	1.57	3.33
5	1.41	***2.28***	8.92	.87	1.31	2.18
6	1.93	9.51	19.38	.52	1.26	1.79
7	1.78	8.77	14.92	.69	1.22	1.74
8	**4.34**	9.94	14.40	1.26	2.30	1.78
9	***1.11***	4.38	8.47	1.19	1.39	1.85
10	1.41	5.42	12.64	.70	1.22	1.83
11	1.26	6.78	17.79	.82	1.24	1.59
12	2.77	7.40	17.27	.57	1.34	1.74
13	1.14	3.49	***6.19***	***.50***	1.22	1.58
14	1.54	4.24	9.93	.67	***.89***	***1.17***
15	1.68	3.76	6.92	.65	1.01	1.39
16	2.13	4.31	8.50	.67	1.02	1.29
17	–	–	–	.79	1.27	1.54

High Values are Bold Face
Low Values are Bold Face Italic
– No Test

APPENDIX D (Continued)

Manhole Casting Size — R-1670, Lid Circumference 75.4″

	Ground Bearing (Not Machined)			Machined Bearing		
Trial	**Test 1**	**Test 2**	**Test 3**	**Test 1**	**Test 2**	**Test 3**
1	**7.61**	**15.46**	19.66	***.44***	1.17	1.42
2	3.79	12.63	16.69	.64	1.57	1.81
3	4.21	14.76	**25.29**	.57	1.22	1.81
4	3.39	10.03	16.74	.96	1.44	1.99
5	3.09	9.49	15.48	1.29	1.99	2.93
6	4.43	10.41	13.78	**2.10**	**4.39**	**6.00**
7	3.44	***8.77***	12.21	1.14	1.93	3.05
8	3.99	13.35	18.53	1.27	2.33	2.97
9	3.57	8.95	17.84	.65	2.25	3.32
10	3.92	14.19	18.03	.74	2.08	3.39
11	4.92	15.43	24.05	.94	2.50	3.61
12	***2.38***	11.59	***11.59***	1.14	2.75	3.81
13	2.82	12.01	15.56	.84	1.53	2.03
14	–	–	–	.54	***.86***	***1.17***

Manhole Casting Size — R-1760, Lid Circumference 78.5″

1	7.35	**17.11**	**25.16**	***.61***	***1.41***	***1.68***
2	***3.45***	***5.84***	11.99	.71	1.66	1.94
3	4.46	8.17	***10.46***	1.38	1.78	2.60
4	6.27	11.54	17.32	1.48	1.85	2.38
5	5.35	12.76	21.18	1.59	2.48	3.82
6	6.32	16.22	20.88	**1.96**	**3.86**	5.18
7	6.57	13.82	19.49	1.39	2.03	3.20
8	8.87	14.35	22.81	1.33	2.88	3.81
9	**8.89**	17.04	21.88	1.38	1.79	2.78
10	6.47	13.38	17.66	1.61	1.98	2.99
11	7.09	12.31	17.30	1.53	2.28	2.78
12	5.52	11.37	14.99	1.71	2.62	3.57
13	4.78	13.25	20.31	1.41	2.02	3.05
14	–	–	–	1.86	3.66	**5.30**

Manhole Casting Size — R-1642, Lid Circumference 81.7″

1	4.29	12.34	17.95	1.40	1.71	2.40
2	3.30	6.39	9.74	1.30	1.95	2.30
3	**5.77**	10.06	19.93	1.19	1.49	2.06
4	3.35	13.66	19.50	***.94***	1.38	1.95
5	4.01	13.01	22.61	**2.99**	**4.34**	**5.45**
6	3.62	12.14	21.53	1.63	1.68	2.20
7	5.63	**18.50**	**26.04**	1.64	2.66	3.57
8	5.27	15.51	23.09	1.07	1.46	1.95
9	3.29	11.50	18.87	1.02	***1.07***	***1.61***
10	3.19	12.00	18.40	1.16	1.39	1.76
11	2.01	***3.82***	***5.70***	1.39	1.63	2.50
12	***1.79***	3.94	5.74	1.85	2.35	3.25
13	3.39	12.38	19.47	1.21	1.54	2.23
14	4.21	13.20	21.18	1.14	1.54	2.00
15	2.68	11.76	13.43	–	–	–
16	2.60	11.64	13.45	–	–	–

APPENDIX E

Raw Test Data for Vent/Pickhole Inflow

Table values shown are water depths in feet as measured in the receiving tank for each trial. Tests lasted one minute. By averaging the ten test trials in each column and multiplying this result by tank factor 33.5431 GPM per foot of depth, the average GPM for each hole diameter is obtained.

Test No. 1

Hole Diameter

Trial	¾″	1″	1¼″	1½″	2″
1	.007	.010	.014	.019	.029
2	.008	.012	.013	.017	.027
3	.007	.011	.013	.019	.026
4	.008	.009	.015	.018	.030
5	.007	.013	.014	.018	.025
6	.008	.011	.014	.018	.027
7	.007	.010	.013	.017	.027
8	.008	.012	.014	.019	.025
9	.008	.011	.015	.017	.029
10	.008	.011	.013	.017	.027
Ave. GPM	.254	.365	.462	.600	.912
Test No. 2					
1	.023	.032	.044	.066	.098
2	.026	.036	.043	.072	.095
3	.023	.034	.047	.069	.094
4	.026	.035	.045	.071	.097
5	.022	.034	.046	.067	.092
6	.026	.038	.046	.072	.089
7	.025	.032	.043	.066	.091
8	.025	.037	.044	.070	.091
9	.024	.033	.048	.069	.097
10	.026	.033	.048	.071	.094
Ave. GPM	.824	1.153	1.522	2.324	3.145
Test No. 3					
1	.071	.132	.186	.276	.463
2	.074	.133	.180	.277	.469
3	.072	.131	.187	.275	.467
4	.074	.127	.185	.277	.465
5	.071	.127	.186	.272	.468
6	.071	.129	.181	.276	.466
7	.072	.128	.178	.276	.460
8	.074	.132	.182	.277	.462
9	.071	.130	.185	.275	.467
10	.073	.133	.187	.275	.467
Ave. GPM	2.424	4.366	6.161	9.243	15.609

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