Herrick Company, Inc.

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BID 19-2017: West Hickman WWTP Zone 2 Aeration Improvements

Specification Section 11375

Item 4.h(4): EPDM Membrane Diffusers and Gaskets –

EDI: Membrane Longevity Test Reports

* HERRICK COMPANY RECEIVED FULL TEST REPORTS AFTER LEAVING OFFICE TO TURN IN BID. WE CAN TRANSMIT REPORTS ELECTRONICALLY IMMEDIATELY IF LOW BID, UPON REQUEST.

Environmental Dynamics International
FlexAir™ 9" Disc Membrane Longevity Report Summaries

Location:	Millbury, MA USA
Months in Operation*:	62
Number of Samples:	3
Durometer Change:	+ 4.2%
Weight Change:	- 1.6%
Permanent Set:	+ 0.1%

Location:	Beijing, China
Months in Operation*:	60
Number of Samples:	4
Durometer Change:	+ 1.0%
Weight Change:	- 1.3%
Permanent Set:	+ 0.2%

Location:	Tokyo, Japan
Months in Operation*:	48
Number of Samples:	4
Durometer Change:	+ 4.2%
Weight Change:	+ 0.6%
Permanent Set:	+ 0.5%

** - at time of testing.*

All data verified by an independent testing agency. Full reports available upon request.

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Specification Section 11375

Item 4.h(4): EPDM Membrane Diffusers and Gaskets –

Sanitaire: Membrane Longevity Test Reports

REDMON ENGINEERING COMPANY

Consulting Engineers

6200 North 39th Street

Milwaukee, Wisconsin 53209-3512

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FAX: (414) 461-2207

e-mail: redmoneng@aol.com

February 11, 2000

Water Pollution Control Corp.
Attn: Mr. Tom Casper
Mr. Mark Raether
9333 North 49th Street
Brown Deer, WI 53223

Re: Las Vegas, Nevada- Sanitaire 9" Silver Series Membrane Discs
Approximately 4 Years Service

Gentlemen,

In late January, 2000 Redmon Engineering Company received five Sanitaire 9" Silver Series membrane disc diffusers, from Las Vegas. Redmon Engineering Company labeled the diffusers B17-6 -1 to 5 upon receipt.

Table 1 summarizes the operating characteristics obtained on the membrane disc diffusers in their "as received" condition and following laboratory scrubbing. Operating characteristics obtained include DWP at air rates of 0.75, 1.0, 2.0 and 3.0 cfm and uniformity of air release as judged by the EFR test and ratios of flux data obtained at 1.0 cfm. Prior to their delivery to Redmon Engineering Company, Sanitaire personel scrubbed diffusers B17-6-1, 2, and 3.

Physical property measurements including weight, specific gravity, Shore A durometer hardness and dimensions were obtained on the cleaned diffusers and are reported as Table 2. Changes to the membrane material due to service may be estimated by comparing the measurements of the membrane discs following service to measurements typical for similar diffusers prior to service.

Unused Silver Series membrane disc diffusers may be expected to have DWP's at 2.0 cfm of about 13.4 in wg. Tested "as received", the two fouled diffusers were measured to have an average DWP at 2.0 cfm of 21.3 in wg, suggesting an increase from new of roughly 7.9.in wg. All five diffusers were cleaned by scrubbing the mixed liquor surface with a medium stiff nylon bristle brush. Following cleaning the average DWP at 2.0 cfm was 17.3 in wg which approximately 3.9 in wg above typical values when new.

At the bottom of Table 1 are listed the average DWP values for new diffusers, fouled diffusers and scrubbed diffusers. These data are plotted as Figure 1. It is apparent from this figure that scrubbing has reduced the DWP increase due to fouling by about 50%.

The four columns of data in Table 1 headed as EFR and Ratios of Flux pertain to measurements made to assess the uniformity of air release across the surface of a diffuser. The acronym EFR stands for Effective Flux Ratio, which is the ratio of effective air flux divided by the apparent flux.

By way of example, if a one foot square perforated diffuser was aerated at 2.0 cfm, its apparent or overall flux is equal to 2.0 scfm per square foot of surface area. If all the air was being uniformly released from half of the total surface area (0.5 square foot in this case), the effective flux rate is 2.0 scfm per 0.5 square foot, or 4.0 scfm per square foot. The EFR in this hypothetical case is 4.0/2.0 or 2.00. A perfectly uniform diffuser is one where the effective flux and apparent flux are equal (EFR = 1.000). Summarizing, the closer the EFR is to 1.00, the more uniform it is, and the greater it is than 1.00, the less uniform it is.

Unused membrane disc diffusers typically have EFRs of about 1.19. The fouled diffusers had EFRs in the range of 1.02 to 1.07. These values indicate the fouled diffuser specimens have substantially more uniform air distribution properties than

typical new membrane diffusers. Following scrubbing the EFR's increased somewhat up to an average value of 1.15. This still represents very uniform air release. As is apparent from the Ratios of Flux data, both the new and scrubbed diffusers are discharging the majority of air out of the central region of the diffuser with less air release in the peripheral region. The fouled "as received" diffusers have almost perfect air release uniformity.

Table 2 reports the physical property characteristics obtained on all five cleaned membrane disc diffusers. Due to the manufacturing process of membrane diffusers, characteristics of membrane disc diffusers of similar manufacture vary to some extent between diffusers of different batches, as well as between diffusers of the same batch. Because of this variability, the effect of service on the membrane material can only be estimated.

The data suggest decreases in weight averaging approximately 0.8% and increases in specific gravity and durometer averaging approximately 0.6% and 3.4%, respectively. Thickness measurements averaging roughly 0.079 inch for unused diffusers compare to measurements averaging approximately 0.078 inch for the used diffusers suggesting an average decrease of about 1.8%. The permanent set data indicates that on the average the diffusers have stretched about 0.2%.

The data obtained on the returned Las Vegas diffusers indicate only very minor changes have occurred with respect to the physical properties of the diffusers following an extended service period. These data indicate that the Silver Series Membranes have very stable properties when exposed to the wastewater/mixed liquor at the plant in question. From a materials point of view, the diffusers are nowhere near their endpoint with respect to their useful life.

A review of the operating characteristics of the diffusers indicates the principal affect of service exposure is an increase in the DWP values of the diffusers. Upon

receipt the fouled membranes had a thin hard layer of foulant adhering to the mixed liquor surface of the diffusers which resulted in an increase in DWP of about six inches water column. External scrubbing reduced the DWP increase to about four inches water column above a typical new diffuser. In light of the laboratory analysis it appears that draining the tanks and scrubbing the diffusers would result in reducing the diffuser operating pressure by about 0.15psi. From an airflow distribution point of view, the air release uniformity of the fouled diffusers is excellent which indicates that the oxygen transfer efficiency is also excellent. It is doubtful that scrubbing the diffusers to achieve a 0.15 psi backpressure reduction is economically justified. The bottom line is that the diffusers appear to be performing in an efficient manner at a slightly elevated pressure and that the membrane material is quite stable in the environment to which is subjected.

If you have any questions or comments, please do not hesitate to contact us.

Best regards,

REDMON ENGINEERING COMPANY

David T. Redmon

TABLE 1
LAS VEGAS - NEVADA
SANITAIRE 9" SILVER SERIES MEMBRANE DISC DIFFUSERS
APPROXIMATELY 4 YEARS SERVICE

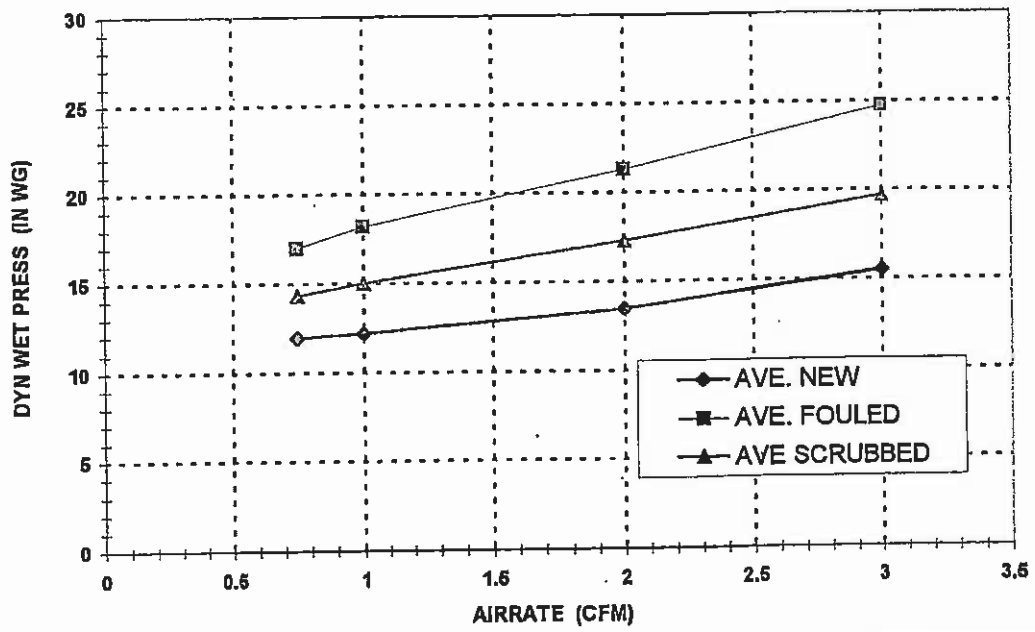
DIFFUSER NO.	DESCRIPTION	DWP				EFR	RATIOS OF FLUX		
		@ 0.75 CFM	@ 1.0 CFM	@2.0 CFM	@ 3.0 CFM	@ 1.0 CFM	CENTER OVERALL	INTERMED OVERALL	OUTER OVERALL
B17-6-1	SCRUBBED	12.65	13.2	15.05	17.15	1.179	1.47	1.23	0.44
B17-6-2	SCRUBBED	14.4	15.35	18.1	20.65	1.242	1.48	1.26	0.39
B17-6-3	SCRUBBED	13.8	14.65	17.2	20.05	1.207	1.02	1.3	0.54
B17-6-4	FOULED AS RECEIVED SCRUBBED 5% HCL SOAK	16.75 14.5 14.4	17.9 15.2 15.1	21.05 17.25 16.9	24.6 19.45 19.2	1.023 1.041 1.277	1 1.1 1.55	1.08 1.12 1	0.87 0.76 0.75
B17-6-5	FOULED AS RECEIVED SCRUBBED	17.25 16.1	18.45 16.7	21.5 18.8	24.85 21.1	1.074 1.056	0.96 1.14	0.96 1.08	1.07 0.81
UNUSED	ESTIMATED NEW	11.95	12.2	13.45	15.5	1.193	1.64	1.13	0.51
AVERAGE	FOULED AS RECEIVED	17	18.2	21.3	24.75	1.05	0.98	1.02	0.97
AVERAGE	SCRUBBED	14.3	15	17.3	19.7	1.15	1.24	1.2	0.59

TABLE 2
LAS VEGAS
SANITAIRE 9" SILVER SERIES MEMBRANE DISC DIFFUSERS
APPROXIMATELY 4 YEARS SERVICE

DIFFUSER NO.	B17-6-1	B17-6-2	B17-6-3	B17-6-4	B17-6-5	ESTIMATED NEW
WEIGHT (GRAMS)	144.57	145.80	144.08	144.90	148.20	146.70
SPECIFIC GRAVITY	1.059	1.064	1.057	1.056	1.057	1.052
DUROMETER	61.00	62.00	60.00	59.88	58.50	58.30
THICKNESS (IN) $\bar{X}$	0.078	0.078	0.076	0.077	0.079	0.079
S/X	0.010	0.008	0.015	0.009	0.01	0.014
PERMANENT SET (IN) 34 CENTERMOST ROWS	3.305	3.305	3.319	3.321	3.319	3.308
	ESTIMATED PERCENT CHANGE FROM NEW					AVERAGE
WEIGHT (GRAMS)	-1.45%	-0.61%	-1.79%	-1.23%	1.02%	-0.81%
SPECIFIC GRAVITY	0.67%	1.14%	0.48%	0.38%	0.48%	0.63%
DUROMETER	4.63%	6.35%	2.92%	2.70%	0.34%	3.39%
THICKNESS (IN) $\bar{X}$	-1.27%	-1.27%	-3.80%	-2.53%	0.00%	-1.77%
PERMANENT SET (IN)	-0.09%	-0.09%	0.33%	0.39%	0.33%	0.18%

FIGURE 1

LAS VEGAS SANITAIRE 9" MEMBRANE DISC DIFFUSERS



REDMON ENGINEERING COMPANY
Consulting Engineers

6200 North 39th Street
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February 12, 2001

Water Pollution Control Corp.
Attn: Mr. Mark Raether
Mr. Tom Casper
9333 N. 49th Street
Brown Deer, WI. 53223

Re: Sanitaire Silver Series I Membrane Diffusers From Kokomo, Indiana

Gentlemen,

On February 9, 2001, Redmon Engineering Company received three membrane disc diffusers that had been returned to Sanitaire's home office from the Kokomo, Indiana Plant. According to our notes, these diffusers have been in service approximately three years.

Upon receipt, the diffusers were labeled B21-10-1 to 3. Based on the notes that came with the diffusers, diffuser #1 was removed near the influent of the tank while diffusers 2 and 3 were removed from the middle and effluent end, respectively. Table 1 summarizes the operating characteristics of the membranes "as received" and following cleaning. Also, included in Table 1 are the operating properties of typical new diffusers of similar manufacture and material. Figure 1 plots the dynamic wet pressure (DWP) of the three diffusers over a range of airflow rates fouled "as received" and the DWP of new diffusers. Figure 2 is a similar plot for the diffusers following cleaning by scrubbing. It is apparent from Figure 1 that the DWP of the three returned diffusers is approximately 2 to 3 inches water column greater than a new diffuser. As shown in Figure 2, scrubbing essentially returned the DWP's to a level like that of a new diffuser.

The four columns of data in Table 1 headed as EFR and Ratios of Flux pertain to measurements made to assess the uniformity of air release across the surface of a

diffuser. The acronym EFR stands for Effective Flux Ratio, which is the ratio of effective air flux divided by the apparent flux.

By way of example, if a one-square foot porous diffuser was aerated at 2.0 cfm, its apparent or overall flux is equal to 2.0 scfm per square foot of surface area. If all the air was being uniformly released from half of the total surface area (0.5 square foot in this case), the effective flux rate is 2.0 scfm per 0.5 square foot, or 4.0 scfm per square foot. The EFR in this hypothetical case is 4.0/2.0 or 2.00. A perfectly uniform diffuser is one where the effective flux and apparent flux are equal (EFR = 1.000). Summarizing, the closer the EFR is to 1.00, the more uniform it is, and the greater it is than 1.00, the less uniform it is.

Typical EFR values for new diffusers average approximately 1.24. "As received" the Kokomo diffusers were observed to have an average EFR of 1.12 and after cleaning 1.11. These results indicate that the uniformity of air release of the Kokomo diffusers fouled "as received" and following cleaning is excellent.

Table 2 and Figure 3 present the physical property characteristics obtained on the cleaned membrane disc diffusers returned for analysis. Due to the manufacturing process of membrane diffusers, characteristics of membrane diffusers of similar manufacture vary to some extent between different batches, as well as between diffusers of the same batch. Because of this variability, the effect of service on the membrane material can only be estimated.

Figure 3 plots the changes in physical properties for diffusers B21-10-1 to 3. As plotted in Figure 3, it is apparent that all of the diffusers have responded similarly to the environment to which they have been subjected based on the parameters of specific gravity, Shore A durometer and permanent set readings. These parameters are the most consistent in the database for similar diffusers. If individual diffusers are thicker or thinner than the database predicts for new diffusers this affects the parameters of

changes in weight and membrane thickness. By way of example, if diffuser B21-10-1 was thinner when new than the database suggests, it would also be lighter than the database indicates. As a result when this diffuser is returned for analysis it will appear that the diffusers has lost weight and gotten thinner. If the diffuser was thicker when new than the database suggests, it would also be heavier than the database indicates. When returned this diffuser would appear to have lost less weight than the other diffusers and not to have decreased in thickness to the same extent of other diffusers that started out closer to the database values. A review of the Kokomo physical property data suggests that diffuser #1 was thinner than the database indicates when new and diffuser #2 thicker than the database indicates. It seems likely that the diffusers have lost about 3% of their initial weights and have become thinner by about 3.7%.

On the basis of this analysis the Kokomo diffusers appear to be in good shape for their age and probably have significant life remaining for this application.

If you have any question or comments on this report, do not hesitate to call me.

Best regards,

REDMON ENGINEERING COMPANY

David T. Redmon, PE

TABLE 1

KOKOMO, INDIANA

SANITAIRE SILVER SERIES I MEMBRANE DISCS

APPROXIMATELY 3 YEARS SERVICE

DIFFUSER NO.		B21-10-1		B21-10-2		B21-10-3		
DESCRIPTION		AS RECEIVED	SCRUBBED	AS RECEIVED	SCRUBBED	AS RECEIVED	SCRUBBED	ESTIMATED NEW
DWP (IN WG)	@ 0.75 CFM	14.30	12.00	14.45	12.00	15.25	13.50	11.35
	@ 1.0 CFM	14.65	12.20	15.10	12.30	15.75	13.75	11.85
	@ 2.0 CFM	15.80	13.50	16.55	13.95	17.15	15.35	13.55
	@ 3.0 CFM	17.05	14.80	18.00	15.65	18.45	16.50	15.70
EFRTC	@ 1.0 CFM	1.104	1.100	1.193	1.219	1.069	1.025	1.236
RATIOS OF FLUX	CENTER/OVERALL	0.77	0.76	1.10	1.38	1.36	1.24	1.68
	INTERMED/OVERALL	0.93	0.97	1.19	1.12	1.09	1.04	1.15
	OUTER/OVERALL	1.20	1.16	0.67	0.65	0.70	0.83	0.47

TABLE 2

KOKOMO, INDIANA

SANITAIRE 9" SILVER SERIES I MEMBRANE DISC DIFFUSERS

APPROXIMATELY 3 YEARS IN SERVICE

DIFFUSER NO.		B21-10-1	B21-10-2	B21-10-3	
DESCRIPTION		SCRUBBED	SCRUBBED	SCRUBBED	ESTIMATED NEW, UNUSED
WEIGHT (GRAMS)		138.70	146.70	142.82	147.16
SPECIFIC GRAVITY		1.059	1.057	1.057	1.053
DUROMETER		61.13	60.75	61.13	58.30
THICKNESS (IN)	$\bar{X}$	0.074	0.080	0.077	0.080
	S/X	0.012	0.043	0.024	0.009
PERMANENT SET (IN)		3.285	3.295	3.294	3.306
CENTERMOST ROWS MEASURED		34	34	34	34
		ESTIMATED PERCENT CHANGE FROM NEW			
		B21-10-1	B21-10-2	B21-10-3	AVERAGE
WEIGHT (GRAMS)		-5.75%	-0.31%	-2.95%	-3.00%
SPECIFIC GRAVITY		0.57%	0.38%	0.38%	0.44%
DUROMETER		4.85%	4.20%	4.85%	4.63%
THICKNESS (IN)	$\bar{X}$	-7.50%	0.00%	-3.75%	-3.75%
	S/X	–	–	–	–
PERMANENT SET (IN)		-0.64%	-0.33%	-0.36%	-0.44%

FIGURE 1
KOKOMO, INDIANA
DWP vs AIRFLOW
DIFFUSERS AS RECEIVED

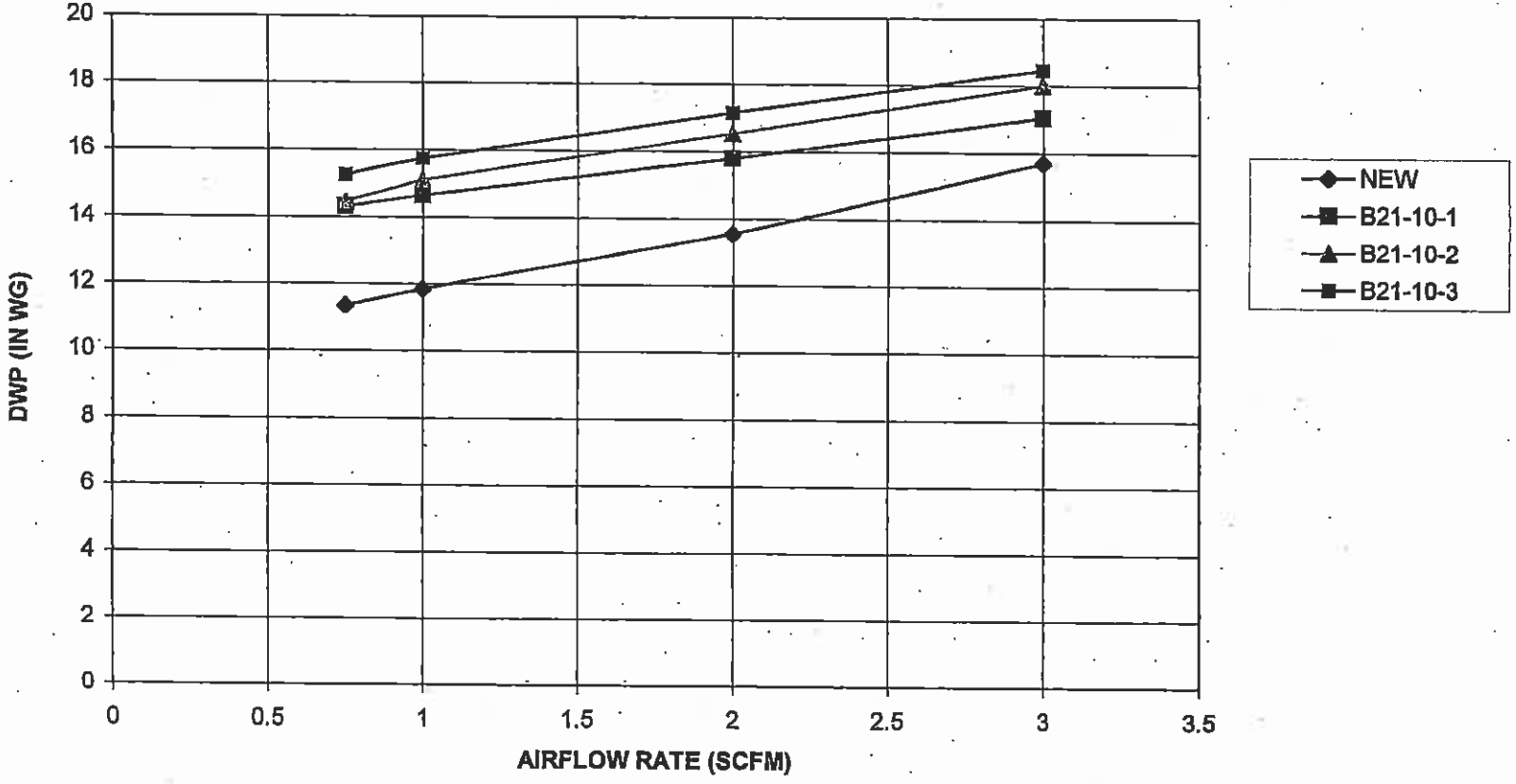


FIGURE 2
KOKOMO, INDIANA
DWP vs AIRFLOW
DIFFUSERS SCRUBBED

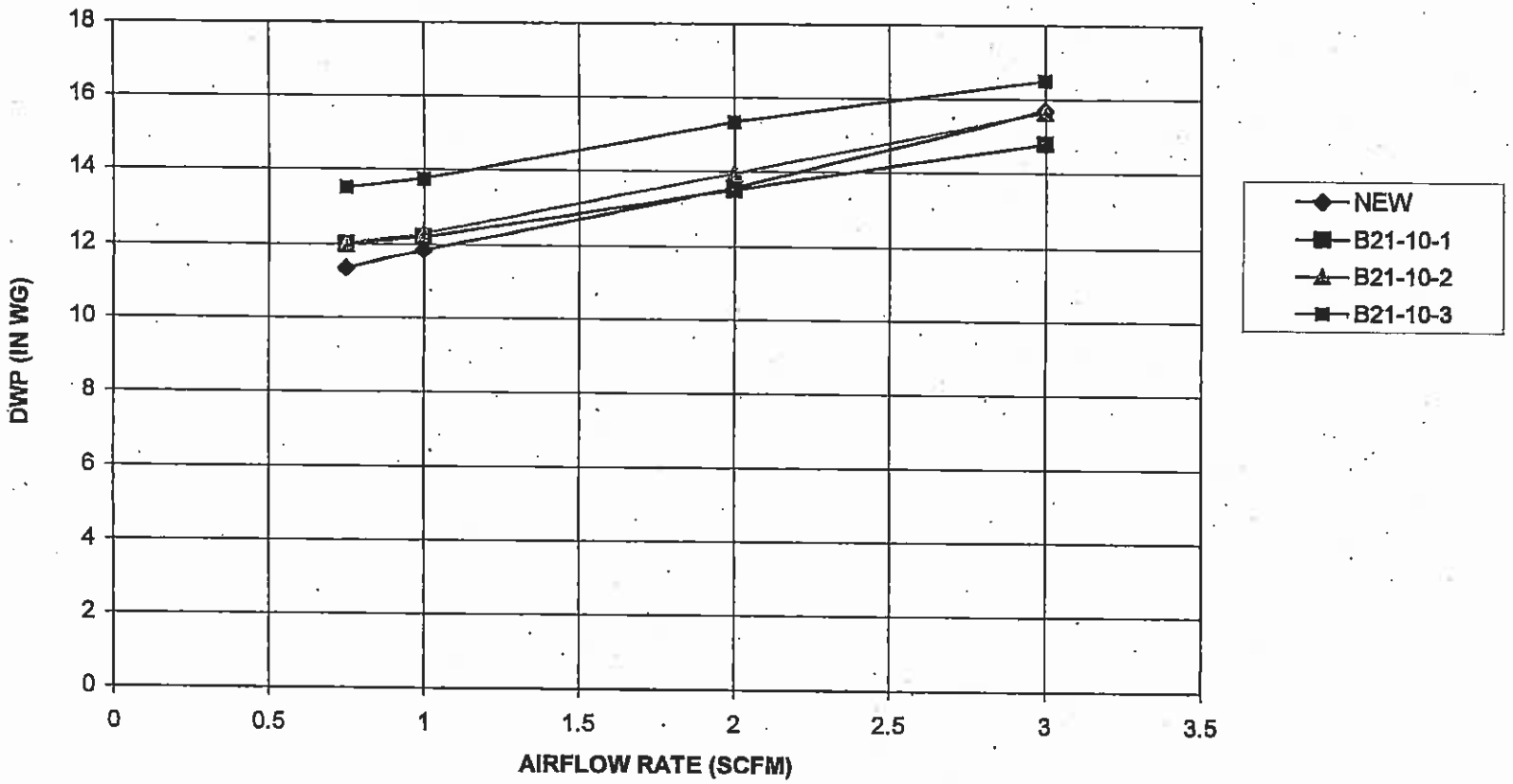
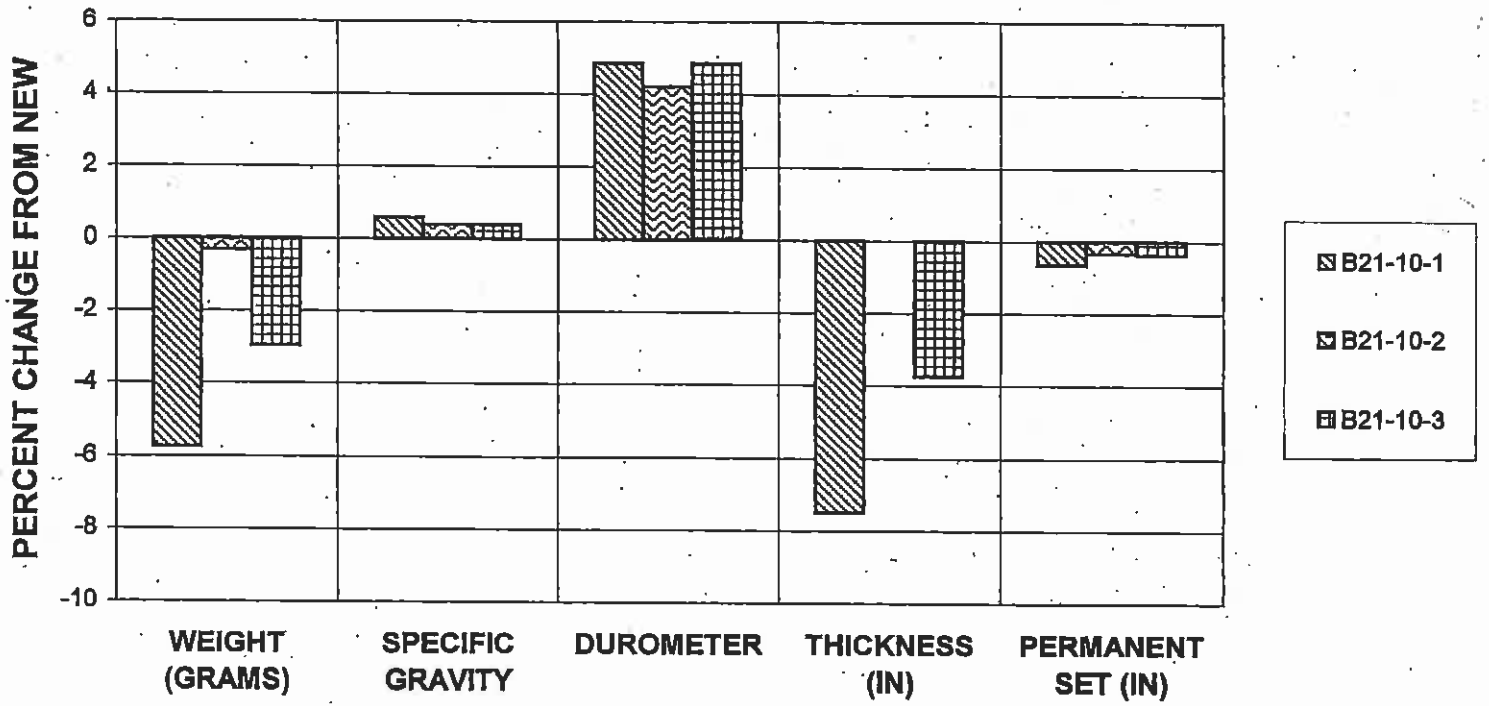


FIGURE 3
CHANGES IN PHYSICAL PROPERTIES
KOKOMO, INDIANA



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7-29-03

Sanitaire
Attn: Mr. Joe Krall
9333 N. 49th Street
Brown Deer, WI. 53223

Re: Sanitaire 9" Silver Series II Membrane Diffusers From Milwaukee South Shore After 3 Years Service

Dear Joe,

On July 17, 2003, Redmon Engineering Company received three 9-inch diameter Silver Series II membrane disc diffusers that had been returned to Sanitaire's home office from the Milwaukee's South Shore Wastewater Treatment Plant. According to our notes, these diffusers have been in service approximately three years. Upon receipt, the diffusers were labeled B27-3-1, 2, and 3. Diffuser B27-2-1 was labeled Middle; diffuser 2 was labeled South; and diffuser 3 was labeled North by the plant staff. All three diffusers were received in a fouled condition.

Table 1 summarizes the operating characteristics of the membranes "as received" and cleaned. Also, included in Table 1 are the operating properties of typical new diffusers of similar manufacture and material. Figures 1 and 2 plot the dynamic wet pressure (DWP) of the three diffusers over a range of airflow rates "as received" and cleaned, respectively along with the DWP of a typical new diffuser of similar manufacture. Both "as received" and cleaned the DWP values of the used diffusers is slightly lower than the DWP values of a typical new diffuser. As received the three diffusers have an average DWP at 2.0 cfm of about 11.55 -inches water column. This value is about 1.3 inches water gauge less than a typical new diffuser. After cleaning by scrubbing the average DWP of the three diffusers at 2.0 cfm is 11.2 inches water gauge, which is 1.65 inches water gauge less than a new membrane.

The four rows of data in Table 1 headed as EFR and Ratios of Flux pertain to measurements made to assess the uniformity of air release across the surface of a diffuser. The acronym EFR stands for Effective Flux Ratio, which is the ratio of effective air flux divided by the apparent flux.

By way of example, if a one-square foot porous diffuser was aerated at 2.0 cfm, its apparent or overall flux is equal to 2.0 scfm per square foot of surface area. If all the air was being uniformly released from half of the total surface area (0.5 square foot in this case), the effective flux rate is 2.0 scfm per 0.5 square foot, or 4.0 scfm per square foot. The EFR in this hypothetical case is 4.0/2.0 or 2.00. A perfectly uniform diffuser is one where the effective flux and apparent flux are equal (EFR = 1.000). Summarizing, the closer the EFR is to 1.00, the more uniform it is, and the greater it is than 1.00, the less uniform it is.

Typical EFR values for new Standard Series I diffusers average approximately 1.41. "As received" the Milwaukee South Shore diffusers were observed to have an average EFR of 1.22. These results indicate that the uniformity of air release of the returned diffusers is better than typical new diffusers. As a result of the more uniform air release patterns the returned diffusers should have better oxygen transfer efficiencies than the same diffusers when new.

Table 2 presents the physical property characteristics obtained on the cleaned membrane disc diffusers returned for analysis. Due to the manufacturing process of membrane diffusers, characteristics of membrane diffusers of similar manufacture vary to some extent between different batches, as well as between diffusers of the same batch. Because of this variability, the effect of service on the membrane material can only be estimated.

On average the returned membranes appear to have increased in weight by about 0.2% and increased in specific gravity and Shore A durometer 1.15% and 4.7%,

respectively. On average membrane thickness appears to have decreased approximately 2.2%. The permanent set data indicates that the membrane diffusers have stretched about 0.33%.

The laboratory test results indicate that on a functional basis the current Milwaukee South Shore Silver Series I membranes are capable of performing in a manner similar to those of new diffusers. The physical data indicate that the diffusers have increased in hardness somewhat and have stretched about 0.3%. The above physical changes are considered very minor and the diffusers are expected to have several more years' service before requiring replacement.

If you have any question or comments on this report, do not hesitate to call me.

Best regards,

REDMON ENGINEERING COMPANY

David T. Redmon, PE

TABLE 1

MILWAUKEE SOUTH SHORE WWTP

SANITAIRE SILVER SERIES II MEMBRANE DISCS

APPROXIMATE TIME IN SERVICE 3 YEARS

DIFFUSER NO.		B27-3-1	B27-3-1	B27-3-2	B27-3-2	B27-3-3	B27-3-3	
DESCRIPTION		FOULED AS RECEIVED	SCRUBBED	FOULED AS RECEIVED	SCRUBBED	FOULED AS RECEIVED	SCRUBBED	ESTIMATED NEW
DWP (IN WG)	@ 0.75 CFM	11.80	11.25	11.55	11.30	10.60	10.45	12.35
	@ 1.0 CFM	11.95	11.45	11.85	11.55	10.80	10.60	12.85
	@ 2.0 CFM	12.80	12.25	12.95	12.50	11.55	11.25	14.65
	@ 3.0 CFM	14.10	13.35	14.40	13.65	13.00	12.15	16.80
EFRTC	@ 1.0 CFM	1.185	1.147	1.161	1.198	1.313	1.384	1.414
RATIOS OF FLUX	CENTER/OVERALL	0.48	0.60	0.27	0.24	0.61	0.66	0.12
	INTERMED/OVERALL	0.86	0.89	0.99	0.96	1.08	0.97	0.90
	OUTER/OVERALL	1.45	1.35	1.34	1.40	1.05	1.21	1.56

TABLE 2

MILWAUKEE SOUTH SHORE WWTP

SANITAIRE 9" SILVER SERIES II MEMBRANE DISC DIFFUSERS

APPROXIMATE TIME IN SERVICE 3 YEARS

DIFFUSER NO.	B27-3-1	B27-3-2	B27-3-3	
DESCRIPTION	CLEANED	CLEANED	CLEANED	NEW
WEIGHT (GRAMS)	156.60	159.22	156.75	157.28
SPECIFIC GRAVITY	1.054	1.060	1.063	1.047
DUROMETER	59.00	59.63	61.00	57.16
THICKNESS (IN) $\bar{X}$	0.092	0.092	0.089	0.093
S/X	0.081	0.078	0.08	0.094
PERMANENT SET (IN)	2.908	2.926	2.913	2.906
CENTERMOST ROWS MEASURED	30	30	30	30
	ESTIMATED PERCENT CHANGE FROM NEW			
	B27-3-1	B27-3-2	B27-3-3	AVERAGE
WEIGHT (GRAMS)	-0.43%	1.23%	-0.34%	0.15%
SPECIFIC GRAVITY	0.67%	1.24%	1.53%	1.15%
DUROMETER	3.22%	4.31%	6.72%	4.75%
THICKNESS (IN) $\bar{X}$	-1.08%	-1.08%	-4.30%	-2.15%
PERMANENT SET (IN)	0.07%	0.69%	0.24%	0.33%

FIGURE 1

MILWAUKEE SOUTH SHORE WWTP
MEMBRANE DISC DIFFUSERS B27-3-1, 2, AND 3
FOULED AS RECEIVED
DWP VS AIRFLOW

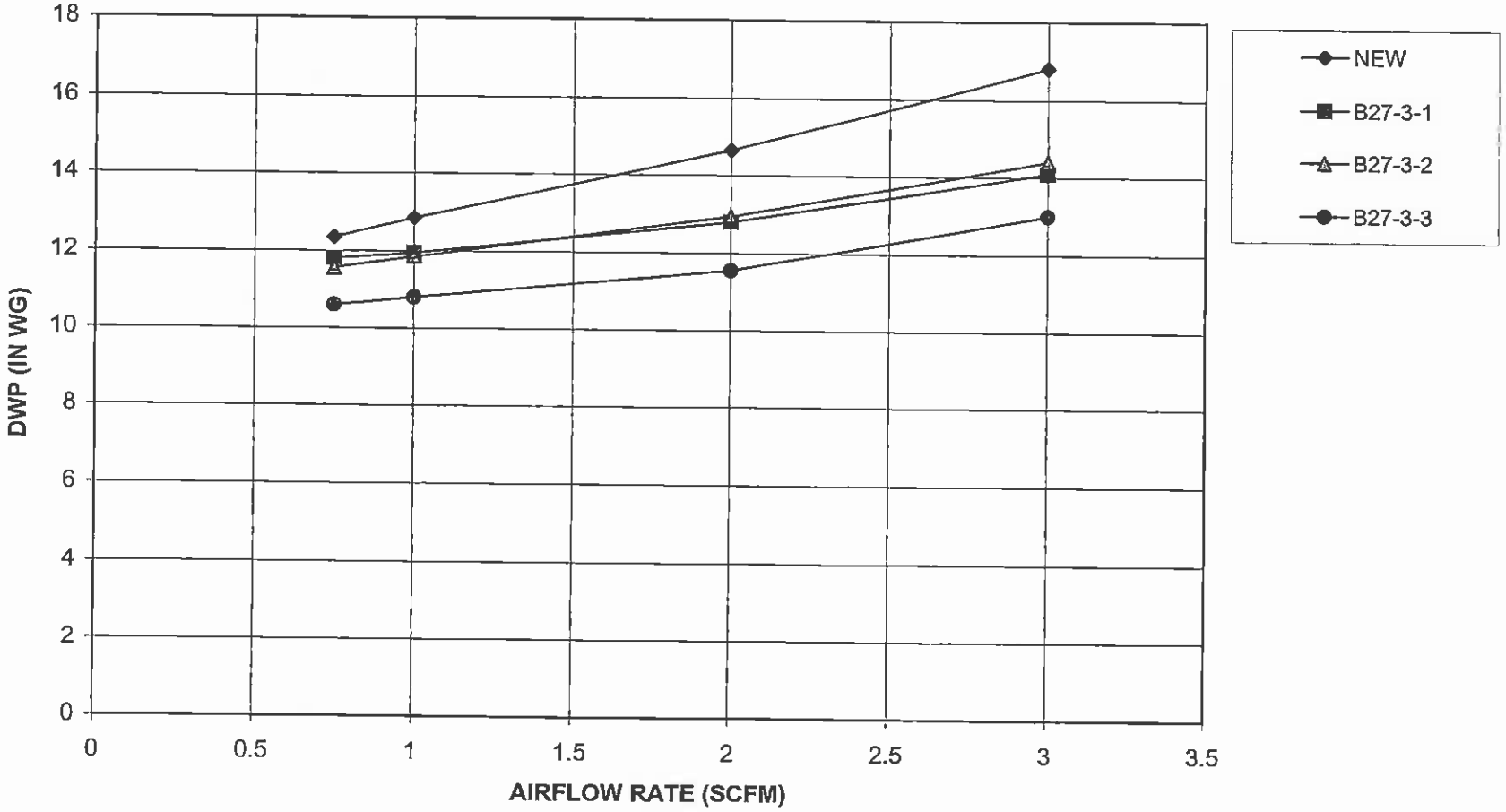

FIGURE 2
MILWAUKEE SOUTH SHORE WWTP
MEMBRANE DISC DIFFUSERS B27-3-1, 2, AND 3
AFTER CLEANING BY SCRUBBING
DWP VS AIRFLOW