Demonstration Projects Program
Technology Transfer
FHWA-DP-39-10
February 1979

DEMONSTRATION PROJECT NO. 39

RECYCLING ASPHALT PAVEMENTS

Kossuth County, Iowa

Prepared for
and
Distributed by

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION 15
DEMONSTRATION PROJECTS DIVISION
1000 NORTH GLEBE ROAD
ARLINGTON, VIRGINIA 22201

Construction Report
"Evaluation of Recycled Asphalt Concrete Pavements"
Kossuth County, Iowa
Project SN-1179(6)

by

Richard P. Henely, P.E.
County Engineer
Kossuth County, Iowa

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Exhibits

Introduction

After some success in the process of recycling asphalt pavement in 1975, Kossuth County decided to implement further recycling projects on a larger scale in its 1976 road construction program. The work done in 1975 indicated that a quality product could be produced, but that an air pollution problem created during the heating and mixing operation must be brought under reasonable control.

As part of its 1976 road program, Kossuth County planned to salvage a total of 16 miles of old asphalt pavements in three projects. Two of these projects were three miles in length and the third project of ten miles. The ten mile project was selected by the Federal Highway Authority as one of the recycling projects to be completed in cooperation with Demonstration Project No. 39, Recycling Asphalt Pavements. The Federal Highway Authority granted $29,750 to the Iowa Department of Transportation for project testing and evaluation.

Cooperation and input into the proposed work was received from many sources. Participants included three offices of the FHWA, two offices and two laboratories of the Iowa D.O.T., the contractor - Everds Brothers, Inc. of Algona, Iowa, the equipment supplier - Barber-Green Company, the Federal Environmental Protection Agency, the Iowa Department of Environmental Quality, the Asphalt Paving Association of Iowa and Kossuth County through its Board of Supervisors and Engineering personnel.

To establish some project parameters, the Iowa D.O.T. Materials Laboratory, as part of the FHWA work plan, evaluated the existing pavement. Roadway samples were subjected to extensive testing to determine the characteristics of the aggregate and asphalt binder. These tests indicated that the existing pavement -

particularly the cold laid base course - contained considerable fines, some 10 or 11 percent passing the 200 mesh sieve and a high percentage of shale and sand size particles. The tests also indicated that the asphalt binder had hardened dramatically over the years. Recovered penetration test values ranged from 16 to 28 and absolute viscosity test values ranged from 14,400 poises to 49,300 poises. When some virgin aggregate and softer asphalt cement were added, a considerable improvement in test characteristics was observed. After plant reprocessing, follow-up tests indicated the blended materials tended to resemble a conventional new mixture. From what we know at this time, it looks as though future asphalt recycled projects can have properly designed and graded mixes.

Kossuth County Project SN-1179(6) was let to contract by the Iowa D.O.T. on April 22, 1976, and awarded to the low bidder, Everds Brothers, Inc., Algona, Iowa, for the amount of $621,418.71. The contract was formally awarded May 13, 1976, by the Kossuth County Board of Supervisors and approved by the Iowa D.O.T. A copy of the contract as it was awarded is shown in Exhibit A. Exhibit B, the title sheet, indicates the location and length of the project, contains the proper approval signatures, and other relative information to the project. Exhibit C contains typical cross-sections of the project before and after construction and special notes which were to be part of the plans and specifications for the work.

When writing a report such as the one now being developed, it is much easier to write about a completely successful undertaking that it is to expound on only a partial success. One portion of the project that was not a success was our inability to reach the required air pollution standards established by the Iowa Department of Environmental Quality and the Federal Environmental Protection Agency.

The main reason for the above failure probably was that too much work was contracted at this one time with too short a completion date allowed for all the work. A total of four projects involving about 82,000 tons of recycling were contracted and tied together; all to be completed in 100 working days or before October 15, 1976. As the contractor did not move in to do the work until the last week in July, it was apparent from the beginning that only God could make a success of this project. The contractor was simply not equipped to accomplish this much work in so little a time and still be able to devote enough time to experiments which would bring the air pollution under reasonable control. As it turned out the contractor did not finish the work until November 2, 1976, at which time he had been fighting cool and cold weather for about ten days or two weeks.

Another disappointment was the inability of the contracting authority to obtain air pollution test results promptly during the mixing operation. If these results had been available promptly, perhaps the contractor or Barber-Greene Company could have made plant adjustments in an effort to bring plant emmissions to an acceptable level. Barber-Green Company did continually test pollution, but their results are probably not available for public inspection and evaluation. It is quite certain that, had the air pollution problem been solved by Barber-Green or Everds Bros, Inc., the process would have been patented or copyrighted by one or both of them. At this point, it should probably be stated that, as long as a contractor or equipment manufacturer is absorbing the costs incurred in the experimental process, the industry can expect a patented process when the problem is solved.

A source sampling report conducted by Entropy Environmentalists, Inc. for the Federal Environmental Protection Agency is hereby referred to and made a part of this report. This report is entitled "Experimental Asphalt Concrete Recycling Plant in Iowa", Number 68-01-3172, dated October 1976, and is noted in reference material at conclusion of this report.

Preliminary Work

The first step in the reconstruction of the new roadway was the extension of existing culverts to accomodate the proposed new roadway design width. Luckily, all but one of the in-place culverts were reinforced circular concrete, and the extension of these was a simple matter. This work was performed by County day labor forces and was not part of the recycling contract. At the road intersection five miles North from the South end of the project a concrete box culvert, which was too short and narrow, was replaced with a large 12 foot diameter corrugated metal pipe. Some anticipated roadway settlement is expected in the area of this pipe even though a good granular backfill material was used in placing the structure.

Reclaiming Asphaltic Pavement

The first contract phase of the work was in the salvaging and stockpiling of the existing asphalt pavement. It should be mentioned here that the contractor, on one of the other recycling projects, attempted to scarify and crush the old pavement on the roadway before loading and stockpiling. This was done by using a Pettibone pulverizing machine. Though the Pettibone machine did pulverize the old pavement to an acceptable maximum 2" size, production was considered by the contractor to be too slow to keep pace with his other equipment. Also, it was the contractor's opinion that maintenance of the Pettibone pulverizing hammers would be too costly and time consuming.

On this project, all of the old pavement was salvaged by first ripping the pavement with two scarifier teeth mounted on the rear of a D-9 tractor. The old pavement broke up quite easily into chunk sizes which could nicely be loaded into ten cubic yard trucks with a three cubic yard rubber-tired loader. To help limit the amount of foreign material, such as dirt and grass, being picked up in the loading process, the sod along the pavement edge was removed by a motor grader and pushed into the road ditch.

It is thought that one of the errors made in the salvaging process was that too much of the fine bituminous treated base was salvaged. It is possible that the fine, asphaltic saturated materials were igniting in the heating and mixing process and causing most of the pollution problem. In future projects, Kossuth County will not try too hard to salvage all of this fine material.

After being loaded into ten cubic yard or 15 ton capacity three axle dump trucks, the salvaged pavement material was hauled an average of three miles to the plant site where it was stockpiled for future crushing. At this point it should be pointed out that, had all virgin aggregate been used in this project, the average haul for aggregates would have been 23 miles. The 33 1/3% virgin aggregate which was incorporated in the asphalt mix was hauled 23 miles, but this gravel pit is now depleted and future virgin aggregate requirements will have much longer haul distances.

The total asphalt mix produced on this project was 42,129 tons. Of this, 2,215 tons were asphalt cement. Calculations indicate that 5.26% asphalt cement was added to the mix on this project. In previous pavement projects using similar aggregates, a design asphalt content of 7 1/2% was normally required.

From the preceding paragraph it can be determined that energy was conserved on 66 2/3% of the required aggregates (0.66) x (42,129 - 2,215) or on 26,622 tons. If the haul distance saved on 26,622 tons of aggregates is 20 miles, then a total of (26,622 x 20 x 2) 1.06488×10^6 ton miles of energy was conserved with respect to the haul of aggregates. According to the Federal Highway Administration (FHWA) published table [1] showing the distribution of highway travel and fuel consumption by vehicle type, a three-axle dump truck consumes 4,270 Btu per ton mile. On this project then, $(1.06488 \times 10^6)\ (4.270 \times 10^3) = 4.5470376 \times 10^9$ Btu was conserved in the aggregate required for the asphalt mix. This amounts to about 36,376 gallons of gasoline or 32,713 gallons of number two diesel fuel.

The asphalt pavement salvaging operations also conserved energy in that a lower amount of asphalt cement was required to be added to the recycled pavement. For work in this area and to obtain a well designed recycled mix, this savings amounts to 2 1/4% on asphalt cement. For a project of the magnitude of 42,129 tons, this amounts to an asphalt savings of 948 tons of asphalt cement. According to energy requirements for producing asphalt cement, "Energy Requirements For Roadway Pavements, the Asphalt Institute, MISC.--75-3, April, 1975," one ton of asphalt cement requires 587,500 Btu to produce same. Then on this project, a total of (487,500 x 948) 5.5695×10^8 Btu of energy was conserved by not adding an additional 2 1/4% asphalt cement.

Due to the fact that 948 (2 1/4%) additional asphalt cement was not required in the final mix, a transportation energy saving was realized. Routinely, asphalt cement is hauled from the refinery in Minneapolis, Minnesota, to Algona, Iowa, and then to the job site. This involves transportation of the asphalt cement an average of 175 miles. Elimination of hauling 948 tons of asphalt cement a one-way distance of 175 miles saves, using the Federal Highway Authority's energy haul table, (175 x 2 x 948) = 7.11×10^5 ton miles of haul. This amounts to an energy savings of ($7.11 \times 10^5 \times 4.27 \times 10^3$) = 3.03597×10^9 Btu's. This savings converts to ($3.03597 \times 10^9 \div 1.25 \times 10^5$) = 24,288 gallons of gasoline or ($3.03597 \times 10^9 \div 1.39 \times 10^5$) = 21,842 gallons of number two diesel fuel.

Energy is required to heat asphalt cement in storage before it is used in the mix. If 948 tons of asphalt cement were conserved on this project, it was not necessary to heat this amount of asphalt before it was used in the mix. The Asphalt Institute[(1)] has estimated that it requires about 6,400 Btu per ton of asphalt cement to heat the asphalt for storage. On this project this amounts to an energy savings of (948 x 6,400) 6.0672×10^6 Btu.

Reclaiming Gravel-Clay Base and Roadway Widening

The process of salvaging the gravel-clay calcium treated subbase and the lowering and widening of the roadway was performed practically in the same operation. First the 4" of gravel-clay subbase were scarified on one half the roadway and windrowed on the other half. Then, with the gravel-clay subbase material windrowed on half of the roadway, the exposed dirt half of road was lowered uniformly 18" by simply pushing the material over the shoulder and compacting with a sheeps-foot roller. When that side of the roadway was lowered, widened and compacted, the process was repeated on the other half of the road. This produced a finished typical road cross-section 34 feet wide with 3 to 1 foreslopes which had a 2 - 4 inch gravel clay surface.

Later, when the subbase was constructed, the salvaged gravel-clay base was incorporated in the project. Had virgin aggregates been used in place of the salvaged gravel-clay, 27,000 tons of virgin aggregates would have been required for the construction of the subbase. Thus, energy was saved in reclaiming the gravel-clay base, mostly in truck haul savings and a small amount in the gravel crushing operation. For the purpose of this paper it will be assumed that the energy conserved due to the elimination of the crushing operation will be negligible because energy was expended in scarifying, windrowing, and salvaging the material even though it was not crushed.

Energy was conserved in both salvaging the gravel-clay base and in the grade lowering and widening operation. On project SN-1179(6) the amount of gravel-clay subbase salvaged and incorporated in the new subbase was about 27,000 tons. Once again, if all virgin gravel had been used in the subbase, the haul distance would have been 23 miles. On the salvaging operation the haul distance was completely eliminated thus saving (23 x 2 x 27,000) 1.242×10^6 ton miles of haul. Using the Federal Highway Authority's energy haul table for three-axle trucks(1). this amounts to a savings of ($1.242 \times 10^6 \times 4.27 \times 10^3$)

5.30334×10^9 Btu's for this portion of the project. This could mean a savings of ($5.30334 \times 10^9 \div 1.25 \times 10^5$) 42,426 gallons of gasoline or ($5.30334 \times 10^9 \div 1.39 \times 10^5$) 38, 153 gallons of number two diesel fuel.

Estimating the energy conserved by lowering and widening the grade rather than truck hauling all the shouldering material is difficult. Normally, on regular shouldering projects of this nature at least 27,500 cubic yards per mile of shouldering material is required. Generally the shouldering material will have an average haul distance of two miles. For Project SN-1179(6), under this assumption, the total yardage of fill required for the project would have been 270,000 cubic yards and the total yard mile of haul would have been (270,000 x 2 x 2) 1.08×10^6 yard miles. By lowering and widening the existing grade, the required fill yardage to be hauled for finish shouldering was reduced to 40,000 cubic yards and (40,000 x 2 x 2) 160,000 yard miles of haul. This indicates a savings of 0.92×10^6 yard miles. If one yard mile equals 1.3 ton miles, then ($0.92 \times 10^6 \times 1.3$) 1.196×10^6 ton miles of haul were saved on this project on the grade widening operation. Again using FHWA tables for three-axle trucks(1) this amounts to a savings of ($1.196 \times 10^6 \times 4.27 \times 10^3$) 5.10692×10^9 Btu's for this part of the project. This conserves 40,855 gallons of gasoline or 36,740 gallons of number two diesel fuel.

Construction of Subbase

Specifications for crushing the salvaged asphaltic concrete pavement required the material be crushed to a maximum 2" seive size with no other gradation being required. Crushing of this material was quite routine and proceeded without serious problems. The only discomfort encountered was the dust situation created in the handling of the material due to it's extremely dry condition. The crushing contractor solved this situation by constantly wetting down the stockpiled material.

Crushing equipment was a primary crusher used for initial breakdown of the material and a standard secondary screening plant. Plant production was practically the same as that for crushing normal gravel aggregates.

Although sizing and gradation of the recycled aggregate were not required on this project, sizing and gradation guidelines on future projects could be specified as might be required for a precisely designed pavement mix. These requirements probably would not necessarily be prone to reduce production rates or increase costs significantly.

There was no significant energy savings in the crushing of the recycled pavements as these materials had to be crushed as would virgin aggregates.

Mixing Recycled Pavement

On Project SN-1179(6), and all other 1976 Kossuth County recycling work, a Barber-Green 10 x 30 drum mixer was used to heat and mix the old pavement. The primary plant modification was an arrangement whereby the burner was backed away from the rotating drum. It was hoped that this would eliminate the direct flame contact with the recyclable asphalt material and reduce initial contact temperatures. In backing the burner away from the drum and by adding a high air output fan, excess air was also introduced at the drum inlet in an effort to cool burner gases and thus lower mix contact temperatures. Neither of these modifications seemed to improve the pollution problem. In fact, the introduction of excess air at the drum inlet may have made the recyclable material more combustible due to the increased supply of oxygen.

In addition to the above modifications, a deflection heat shield was also placed in the inlet end of the drum mixer to deflect the flow of the hot gases and prevent impingement of these gases on the asphalt. This change was also not effective in reducing the pollution problem.

Sadly, the modification which, for a very short period of time, seemed to have the most effect on improving the air pollution was when the fine recyclable aggregates were separated from the coarse recyclable aggregates. Then, with a structurally underdesigned anger device, the fine recyclable aggregate was introduced into the rear end of the drum mixer. Because of the structurally underdesigned anger, this method of operation only lasted a couple of hours due to a permanent breakdown of the angering device. It was during this operation that the most notable improvement in the pollution problem was noticed. In the future, perhaps Barber-Greene should pursue this method of pollution control further.

Various proportions of recycled materials and virgin aggregates were used in the experimentation process. The percentage of recycled material incorporated varied from 30% to 66 2/3% with the balance being made up of 3/4" crushed virgin gravel aggregates. Naturally, as the percentage of recycled materials incorporated was reduced, the percentage of added asphalt cement was increased in an effort to maintain overall constant residual asphalt content.

Regardless of the proportioning of materials to be incorporated in the mix or the equipment modifications made, the pollution problem still persisted. The Barber-Green Company, through its field laboratory, constantly monitored and tested various measuring devices located at critical locations within the pollution control system. Some of the factors measured were temperatures at several locations within the drum mixer and in the pollution control system, pressure drops in the venturi, and stack emissions.

A wet wash scrubber system of pollution control was employed in the asphalt plant configuration. An inter-departmental memorandum dated January 19, 1976, within the Iowa Department of Environmental Quality established minimum parameters required by the D.E.Q. for the removal of particles in the one micron range.

These parameters were made available to all contractors and engineers before the work was let to contract. A copy of this memorandum is shown in Exhibit D.

Energy was conserved in the heating and mixing process. Probably the main reason for this was the dry condition of the salvaged asphalt. As indicated earlier, it was so dry that it was necessary to wet down the stockpile while the material was being crushed to keep the dust down. It is highly possible that the salvaged asphalt material was even absorbing moisture though this possiblity was not verified. Another possible reason for energy conservation in the heating and mixing process was that the characteristics of the salvaged materials was such that it retained the ambient heat of the season while in the stockpile.

It is regrettable that Kossuth County was unable to precisely document fuel requirements in the asphalt pavement heating and mixing process. However, the contractor doing this work was familiar with and had done nearly all of Kossuth County's asphalt work in the past.

In talking with the contractor - Mr. Doug Meyer, President of Everds Brothers, Inc., - on several occasions he emphasized the fact that less energy, or fuel, was being consumed in the heating and mixing process. He stated that in past years and on similiar projects using all virgin materials in this same location, that at least 2 1/2 gallons of number two diesel fuel were required per ton of asphalt produced. He also stated that on most occasions - mostly due to the high moisture content of the local virgin aggregates - that closer to 2 3/4 gallons of number two diesel fuel were required per ton of mix.

He also confirmed our suspicion that less number two fuel was being consumed by stating that the fuel consumption on this project was running between 1.9 and 2.0 gallons of fuel per ton of mix.

From the above, we should be safe in assuming that a minimum of one-half gallon of number two diesel fuel per ton of mix produced was conserved on this project in the mixing process. Again, using the Asphalt Institute's copyrighted document "Energy Requirements for Roadway Pavement", MISC-75-3, April 1975, we can estimate that, on SN-1179(6), $(42,129 \times 0.5 \times 1.39 \times 10^5)$ 2.92796×10^9 Btu's were conserved and that this energy savings can be attributed to the fact that recycled asphalt pavement aggregates were being used.

Pavement Laydown

There were no problems incurred in the paving operation. A full-width Barber-Green paver was used to do the work. Vibratory and pneumatic rollers were used for compaction. Generally, 94 percent minimum required density was obtained quite easily until ambient temperatures in the fall dropped toward the end of the project.

Even with all virgin material being used in asphalt work in this area, low laboratory density values and high voids are encountered. Knowing this before the recycling work began, these characteristics dictated that the percent of added asphalt cement be higher than in other areas of the State of Iowa.

The recycled asphalt mix produced looked exactly as though 100% virgin aggregates were used before and after laydown. The finished pavement surface looked as good or better than conventional pavement.

Lab and Field Testing

Laboratory analysis, involving proposed pavement design mixes, laboratory densities, asphalt extraction tests, etc., were performed by the Iowa Department of Transportation District and Central Laboratories. All field tests and samples were handled by the Kossuth County Engineer's Office. Due to the fact that the project specifications did not establish any specific aggregate gradations, there were no sieve analysis taken of these materials on the cold feed belt.

Exhibit E shows the results of some of the tests ran. These are enlightening in that this exhibit clearly indicates that the residual asphalt penetration decreases as the percent of virgin aggregates is increased and that at the same time the viscosity decreases. By using a higher penetration asphalt, rather than 120-150 which was used on this job, these characteristics can probably be improved in future pavement design.

Energy Conserved

Of course, with this method of construction, Kossuth County's short supply of gravel aggregates are conserved as well as the world's supply of asphalt.

At the moment, the big savings is in the conservation of energy. Though it was and is nearly impossible to precisely document these energy savings, it is highly possible to make an educated estimate when various factors are known or assumed. The following table should give the reader some indications as to the energy savings that can be realized in recycling asphalt pavements, or entire roadways for that matter.

Project SN--1179(6) Kossuth County, Iowa

Item Where Energy Saved	Estimated Energy Conserved		
	Btu's	Gasoline	#2 Diesel Fuel
(1) Reclaiming Pavement	4.570376×10^9	36,376	32,713
(2) Reclaiming Gravel	5.30334×10^9	42,426	38,153
(3) Lowering & Widening Grade	5.10692×10^9	40,855	36,740
(4) Asphalt Storage	0.55695×10^9	4,456	4,007
(5) Asphalt Transportation	3.03597×10^9	24,288	21,842
(6) Heating & Mixing Asphaltic Concrete	2.92796×10^9	23,424	21,065
TOTALS	21.501516×10^9	171,825	154,520

It should be pointed out that the preceding estimates were arrived at by using, hopefully, good common sense calculations with the assistance of the Asphalt Institue Publication concerning energy requirements for roadway pavements.

Costs - Virgin Vs. Recycled

Though recycling is desirable due to the savings of energy and natural resources, a good engineer will determine the most desirable method of constructing a project from the standpoint of economics and the environmental impact. On Project SN-1179(6), the recycling project as was complete was initially compared to a construction improvement of placing 4" asphaltic concrete on the existing pavement and shouldering with an additional 4 foot and six foot shoulders on each side of the pavement. This method also required that an additional $10,000 per mile be considered as part of the project cost. When these two methods are compared, we find that there is a cost savings of $138,418.33 or $13,852 per mile when the recycling method is constructed. Exhibit F shows the actual construction cost of recycling as compared to the estimated cost of using the conventional method.

Summary

As a result of this report and this experience, it can be said that under specific condition of aggregate scarcities, where road widening is required, or where energy and natural resource conservation is of prime importance, then serious consideration should be given to recycling the old asphalt pavements as wellas the reconstruction and widening of the old roadway. This particularly after the air pollution problem caused by the mixing process is solved; and it will be solved.

References

(1) "Energy Requirements for Roadway Pavements," The Asphalt Institute, MISC-75-3, April 1975.

(2) Source Sampling Report, "Experimental Asphalt Concrete Recycling Plant in Iowa", No. 68-01-3172, Ocotber 1976.

EXHIBITS

Exhibit A

Highway Division

CONTRACT

NO 12323

FORM 383 D 3-74 H-4974

Type of Work ASPHALTIC CONC. PAVEMENT

Project No. SN-1179(6)--51-55

COST CENTER 801000 OBJECT 860

Miles 10.065

County KOSSUTH

ON SECONDARY ROAD FROM THE SW COR. SEC. 3-97-27 NORTH APPROX. 10 MILES TO IOWA 9

THIS AGREEMENT made and entered by and between the Iowa Department of Transportation, Des Moines, Iowa, consisting of the following members: ROBERT R RIGLER, STEPHEN GARST, DONALD K GARDNER, ALLAN THOMS, W. F. MCGRATH, ANN PELLEGRENO, & L. STANLEY SCHOELERMAN, party of the first part, and 1330 ERDS BROTHERS, INC. OF ALGONA, IOWA

party of the second part.

WITNESSETH: That the party of the second part, for and in consideration of $ ****651,418.71, payable as set forth in the specifications constituting a part of this contract, hereby agrees to construct various items of work and, or, to supply various materials or supplies in accordance with the plans and specifications therefor, and in the locations designated in the notice to bidders, as follows:

ITEM	Quantity	Unit	Unit Price	Amount
BASE, RECLAIM, CRUSH & STOCKPILE BITUMINOUS CONCRETE	128,192	SQ. YDS.	1.13	144,856.
RECONSTRUCTION OF SUBGRADE	9.516	MILES	11,347.00	107,978.
SUBBASE, CONSTRUCTION OF SOIL AGGREGATE	9.932	MILES	3,200.00	31,782.
BASE, RECYCLED ASPHALTIC CONCRETE	44,838	TONS	4.85	217,464.
PRIMER OR TACK-COAT BITUMEN	5,196	GALS.	.50	2,598.
ASPHALT CEMENT	1,719	TONS	81.00	139,239.
MOBILIZATION COST		LUMP SUM		7,500.
			GRAND TOTAL	$651,418.

Exhibit A.

Party of the second part certifies by his signature on this contract that he has complied with 324.17(8) of the 1975 Code of Iowa as amended.

Said specifications and plans are hereby made a part of and the basis of this agreement, and a true copy of said plans and specifications is now on file in the office of the Iowa Department of Transportation under date of APRIL 22, 1976

That in consideration of the foregoing, the party of the first part hereby agrees to pay the party of the second part, promptly and according to the requirements of the specifications the amounts set forth, subject to the conditions as set forth in the specifications.

The parties hereto agree that the notice and instructions to bidders, the proposal filed herein, the general specifications of the Iowa Department of Transportation for 1972, together with special provisions attached, together with the general and detailed plans, if any, for said project -1179(6)--51-55, together with second party's performance bond, are made a part hereof, and together with this instrument constitute the contract between the parties hereto.

That it is further understood and agreed by the parties of this contract that the above work shall be commenced on or before, and shall be completed on or before:

Approx. or Specified Starting Date or Number of Working Days	Specified Completion Date or Number of Working Days
100 WORKING DAYS	OCT. 15, 1976

That time is the essence of this contract and that said contract contains all of the terms and conditions agreed upon by the parties hereto.

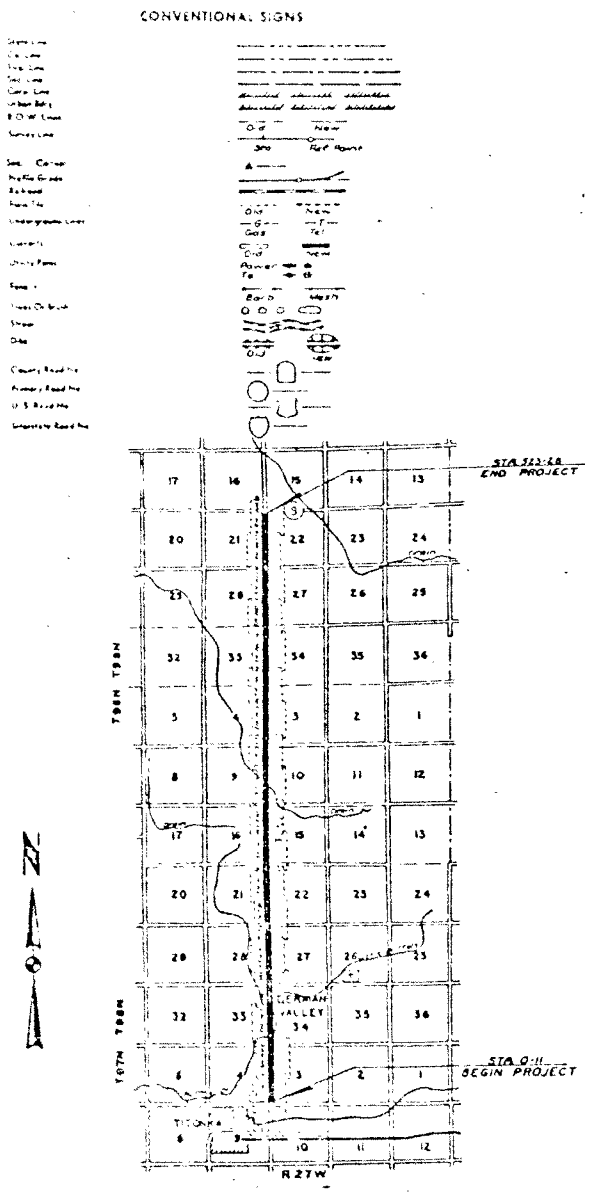
IN WITNESS WHEREOF the parties hereto have set their hands for the purpose herein expressed to this and three other instruments of like tenor, as of the ____ day of MAY 13 1976, 19__

IOWA DEPARTMENT OF TRANSPORTATION

By [signature]
Party of the First Part

EVERDS BROTHERS, INC. OF ALGONA, IOWA

By [signature]
Party of the Second Part



IOWA
DEPARTMENT OF TRANSPORTATION
Highway Division

PLANS OF PROPOSED IMPROVEMENT ON THE

FARM TO MARKET SYSTEM
KOSSUTH COUNTY

SN-1179 (6) -- 51-55

SCALES AS NOTED

THE STANDARD SPECIFICATIONS, SERIES OF 1972, OF THE IOWA STATE HIGHWAY COMMISSION, SHALL APPLY TO CONSTRUCTION WORK ON THIS PROJECT.

INDEX OF SHEETS

Plan & Profile available in County Engineers office

MILEAGE SUMMARY

Total Length of Project Sta. 0+11 to 523+28	= 53,317.0 Ft.
Deduct for Bridge Sta. 60+58	55.0 "
Deduct for Bridge Sta. 89+275	55.0 "
Deduct for Bridge Sta. 108+01	42.5 "
Deduct for Intersection Sta. 154+94.6	22.0 "
Net Length of Project	53,142.5 Ft. = 10.065 Miles

Exhibit B

Detail Plans reduced in size (Do Not Scale)

APPROVED

[signature]

[signature]

[signature]

[signature]

[signature]

BOARD OF SUPERVISORS

3065

I hereby certify that this plan was prepared under my supervision and that engineering decisions with regard to the design were made by me or by other duly registered professional engineers under the laws of the State of Iowa.

[signature]

IOWA REGISTRATION NUMBER DATE

Department of Transportation Iowa — Highway Division

Approved [signature] 3/30/76

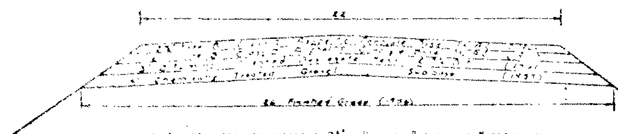
Deputy Chief Engineer Date

A.D.T. 361-170 V.P.D. (1971)

KOSSUTH COUNTY PROJECT NO. SN-1179 (6) -- 51-55 SHEET NO. 1

Exhibit C

TYPICAL CROSS SECTION
Sta 0+11 to 523+25
(Present Roadway)



[illegible] will scarify existing 7½" Nominal Bituminous Material in [illegible] as to salvage the maximum amount of the Bituminous Material. [illegible] will load the Bituminous Material and haul to plant site where [illegible] will be crushed or pulverized to a 2" maximum size. No other [illegible] will be specified. The contractor shall take all [illegible] to prevent contamination and [illegible] of the salvaged material. [illegible] bid will be on a sq. yd. basis and will include [illegible] salvaging, loading, hauling, and [illegible]. [illegible] will cut 500 off roadway edge before salvaging Bituminous Material.

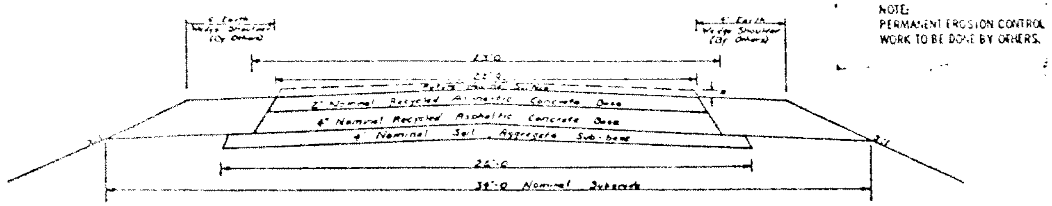
The plant site will be located in the S.W.¼ S.W.¼ Section 21-98-27 on property under lease to Kossuth County. The contractor shall have full use of this location during construction at no cost.

After the Bituminous Material had been removed, the contractor will remove the first 4" chemically treated gravel sub base by stockpiling 1/2 of [illegible] width and windrowing on the other 1/2 of the subgrade. The [illegible] will [illegible] the exposed subgrade an average depth of 16". [illegible] of the sub grade will be accomplished by [illegible] and by means of [illegible] blading the [illegible] material to the foreslopes. After 1/2 of the sub grade is [illegible], the salvaged chemically treated gravel base will be [illegible] and the remainder of the sub grade will be [illegible]. It is intended that the finished sub grade will have a nominal width of 34.38 with 3:1 slopes.

[illegible] on the foreslopes, after thorough disking, shall be removed [illegible] and placed on the area to be occupied by the outer portion of [illegible] in layers not over 8" in loose thickness. The [illegible] shall be notched as required by the engineer in steps as [illegible] is [illegible] and widened. The material will be placed on the [illegible] in layers not [illegible] 6" loose thickness. After the layer has been [illegible] and before the next layer is deposited upon it, the layer shall be compacted with a minimum of one rolling per inch of depth of each lift, and it is further required that the roller continue operation until it is supported on its tamping feet or the equivalent.

The price bid for "Construct 4" Soil-Aggregate Sub-Base" will include all salvaging operations as previously mentioned as well as constructing 4" Soil Aggregate Sub-base (using salvaged material).

TYPICAL CROSS SECTION
Sta 151+94.5 to 523+00.0
Reconstructed Grade



GRADATIONS:

The following gradation data were accumulated for designing and estimating purposes. Their appearance on the plans does not constitute a guarantee that conditions other than those indicated will not be encountered.

SIEVE ANALYSIS - PERCENT PASSING

	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Approximate extracted gradation of pavement to be recycled	100	99	92	82	68	54	39	22	12	8.9
Approximate gradation of gravel furnished by county.	100	98	94	85	69	46	22	8.8	3.4	2.4

POLLUTION TESTING

At the end of the two weeks of production of the asphalt plant, the contractor shall be prepared to subject the plant operations to the Environmental Protection Agency Method 5 Pollution Test to determine whether asphalt plant is in compliance using recyclable aggregates. Subsequent E.P.A. Method 5 Tests may be required by the Iowa Department of Environmental Quality

Prior to the initial E.P.A. Method 5 Test, and for subsequent tests required, the contractor awarded this work shall furnish [illegible] design engineering and testing at the contractor's expense.

The contractor awarded this work shall furnish all labor, equipment, scaffolding, necessary [illegible] and [illegible] and electricity required to conduct E.P.A. Method 5 Tests at contractor's expense. The cost of E.P.A. Method 5 Testing procedures shall be paid by Kossuth County. The contracting authority will not be responsible for delays and expenses incurred by the contractor in meeting, or failing to meet, pollution requirements or in testing and evaluation for that purpose.

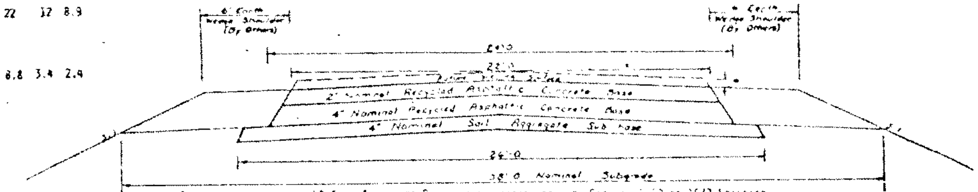
MOBILIZATION

Partial payment for Mobilization will be made as follows: When 5% of the original contract amount is earned, the contractor will be paid 50% of the contract amount for Mobilization. When 10% of the original contract amount is earned, the contractor will be paid the remainder of the contract amount for Mobilization.

The contracting authority reserves the right to cancel the contract or any uncompleted item or portion thereof if the project work cannot be completed as contemplated. Article 1109.05 shall apply, except that payment at the contract price for each unit of completed work shall be full payment for that work, and the contractor will be paid any unpaid amount for the item of Mobilization.

NOTE:
PERMANENT EROSION CONTROL WORK TO BE DONE BY OTHERS.

TYPICAL CROSS SECTION
Sta 0+11 to 151+94.5
Reconstructed Grade



Contractor to prepare 4" Soil Aggregate Sub-base in accordance with Section 2210 of 1972 Standard Specifications.

Contractor will construct a 6" Recycled Asphaltic Concrete Base using a mixture of Recycled Asphalt material, added asphalt cement or asphalt emulsion, and crushed gravel aggregates as determined by job mix. Section 22[illegible], 1972 Standard Specifications, shall apply amended as follows:

1. In any section where Asphalt Treated Base appears, it will be assumed to read "Recycled Concrete Base."
2. Delete Section 2202.02B and insert in its place - The mineral aggregate used will be the salvaged asphalt pavement material, with or without virgin aggregates, crushed or pulverized so that all particles pass a 2" sieve. There will be no other gradation specifications or requirements. The best general practice is to prevail and only methods, equipment, and workmanship of the first quality are to be used. Changes in procedures shall be approved by the engineer.
3. Delete Section 2202.0[illegible] and insert in its place: It will be [illegible] by the [illegible] that the existing [illegible] of type [illegible] asphaltic concrete base and [illegible] base be maintained and kept free from contamination and segregation during the salvaging, [illegible] and/or pulverizing, and placement in the cold feed bins. The additional asphalt cement or asphalt emulsion required to be added to the salvaged material will be determined [illegible] as may be determined by subsequent laboratory testing. The asphalt cement or asphalt emulsion [illegible] shall be maintained within plus or minus [illegible] percentage points tolerance of the [illegible]. The best general practice is to prevail and only methods, equipment, and workmanship of the first quality are to be used. Changes in [illegible] shall be approved by the engineer.
4. It is intended that the bottom lift of "Recycled Asphaltic Concrete Base" shall be constructed in a nominal 4" compacted depth with an estimated additional [illegible] asphalt cement or asphalt emulsion. The upper nominal 2" compacted thickness of "Recycled Concrete Base" shall be constructed with an additional estimated [illegible] asphalt [illegible].
5. For estimating purposes the percent of virgin gravel aggregates to be added to the salvaged bituminous material is 35 1/3%. This percentage may be changed during construction and vary between 25% and [illegible] depending on what percentage best [illegible] the pollution [illegible].
6. Add the following to Section 2202: It is not intended to use an asphalt softening or rejuvenating agent, however, if the engineer, at the time of production, determines that a softening or rejuvenating agent is required, the contractor will add the prescribed agent and will be paid invoice price plus 15% for the cost of the softening agent furnished.

The contractor awarded this work will cooperate fully with the Iowa Department of Environmental Quality and [illegible] his assistance in the form of labor, scaffolding materials, and equipment necessary to perform air pollution tests that may be required by the Iowa Department of Environmental Quality. [illegible] or [illegible] advised to contact the Iowa Department of Environmental Quality, Rexford Walker, Phone No. 515-265-8234, before submitting a bid.

*The maximum allowable slope is 3.0% and the minimum allowable slope is 1.5%. Sections may be modified as directed by the engineer through areas of special shaping.

Reclaim, Crush and Stockpile Bituminous Concrete Base	Reconstruct Sub-Grade	Construct 4" Soil Aggregate Sub-base	Recycled Asphaltic Conc. Base	Primer or Tack Coat Bitumen	Asphalt Cement or Emulsified Asphalt (Residue)	Mobilization Cost
Sq. Yd.	Miles	Miles	Tons	Gals.	Tons	Lump Sum
(4)(6)(7)	(7)(8)(9)(11)(12)	(7)(8)	(1)(2)(7)	(6)(7)	(3)(5)(7)	
128,192	9.516	9.932	44,838	5196	1719	$7500.00

FOOTNOTES:

(1) Drum Mixing Equipment complying with Section 2001 may be used for production of Recycled Asphaltic Concrete Base.

(2) Gravel aggregate to be added to the Salvaged Bituminous Material will be furnished cost free to contractor in stockpile at plant site located in the S.W.¼ S.W.¼ Section 21-98-27.

(3) Estimated at 3½% for Bottom 4" lift. Estimated at 4½% for top 2" lift.

(4) Estimated at 47,360 tons salvaged bituminous material.

(5) Contractor will use 120-150 penetration Asphalt Cement. If required, the emulsified asphalt shall meet AASHTO requirements for grades SS-1 or CSS-1 as designated by the engineer.

(6) All or any part may be eliminated at the discretion of the engineer.

(7) Section 1109.03 of 1972 Standard Specifications shall not apply.

(8) Final payment will be based on estimated planned quantities without remeasurement.

(9) Estimated at 79,375 C.Y. based on average cut of 18".

(10) [illegible] shouldering, after the Asphaltic Concrete is placed, will be done by others and is not a part of this contract.

(11) The contractor shall aerate, compact, and shape all unstable [illegible] prior to construction the soil aggregate sub base. Unstable areas that develop during subsequent construction operations shall be repaired in accordance with the specifications and to the satisfaction of the engineer. All aeration, compaction, shaping and repair shall be incidental to the work and not measured for payment.

(12) Gravel crossroad intersections, driveways, bridges, and field entrances will be shaped to meet the new guideline. The subgrade depth will be tapered at the B.O.P., E.O.P., and paved road intersections to meet existing grades. This work will be considered incidental to the price bid for "Reconstruction of Sub-Grade".

EXHIBIT D

STATE OF IOWA
DEPARTMENT OF ENVIRONMENTAL QUALITY
DES MOINES, IOWA 50316

MEMORANDUM

To: R. A. Walker Date: January 19, 1976

From: Leo Classen, P.E. LC Re: Recycling Asphalt
Permits Section Kossuth County

After reviewing Mr. Henely's letter of December 16, 1975, we offer the following comments.

1. We fully endorse the concept and offer our cooperation in solving the problem of meeting air pollution control regulations.

2. Our observations of the experimental run last September as discussed in Mr. Woll's report of September 30, 1975, and Mr. Walker's letter of December 10, 1975, point out that the process used at that time would not meet our existing regulations.

3. We can not offer a solution to the problem but will outline our recommendations for any future experiment.

4. We believe the observed emissions consisted of a high percentage of small particles one micron or less in size. In order to remove an acceptable percentage of these particles, a medium energy scrubber will be required.

5. We have calculated various venturi configurations and believe that the minimum parameters for the removal of particles in the one micron range are:

   a. A throat velocity of 200 feet per second.
   b. Water injection rates from 8 to 10 GPM per 1000 CFM
   c. An air pressure drop through the venturi in the 20 to 25 inch water gauge range.

6. Other types of scrubbers with efficiencies above 95% may be a possible substitute for a venturi. We do not believe fabric filtration or dry collection devices can be used because the asphalt-coated particles would blank-off or clog these devices in a short time.

7. We will evaluate any proposed control device but will not issue a permit other than an experimental permit with the condition that a stack test be made within two weeks of startup.

8. Any contractor who is awarded this contract should be advised of the construction permit requirements and informed to contact us as early as possible on any permit questions.

LC:mah

Project SN-1179(6)--51-55

Date Sampled	Material	Intended % Asphalt Added	Tank Meas % AC Added	% AC Extracted Total	Recovered AC Pent.	Absolute Viscosity	Kinematic Viscosity
9-29-76	67% Recycled 33% Virgin	4.75	4.88	8.50	51	3775	545
9-30-76	67% Recycled 33% Virgin	4.75	4.87	7.80	44	5954	658
10-11-76	67% Recycled 33% Virgin	4.75	4.89	7.10	58	3239	495
10-12-76	67% Recycled 33% Virgin	4.75	4.96	7.90	47	4975	601
10-13-76	50% Recycled 50% Virgin	5.75	5.80	7.80	67	2318	440
10-20-76	67% Recycled 33% Virgin	4.75	4.76	8.00	43	6470	684
10-21-76	67% Recycled 33% Virgin	4.75	4.78	7.80	41	6740	694
10-22-76	67% Recycled 33% Virgin	4.75	4.83	7.70	39	8800	772
10-26-76	50% Recycled 50% Virgin	5.75	5.89	7.30	57	3100	483
10-27-76	40% Recycled 60% Virgin	6.25	6.39	7.40	71	2210	440
10-28-76	30% Recycled 70% Virgin	6.25	6.28	7.40	86	1423	351
10-29-76	67% Recycled 33% Virgin	5.10	5.12	7.60	48	4160	560
11-1-76	50% Recycled 50% Virgin	5.75	5.87	7.70	62	2772	456

EXHIBIT F

Actual Recycled Project Cost

Item No.	Item	Unit	Unit Price	Quantity	Amount
1	Base, reclaim, crush & stockpile	Sq.Yd.	1.13	128,192	144,856.96
2	Reconstruction of sub-grade	Mile	11,347.00	9.516	107,478.05
3	Sub-base, Construction of soil aggregate	Mile	3,200	9.932	31,782.40
4	Base, Recycled Asphaltic Conc.	Ton	4.35	42,129	204,327.83
5	Primer or tack-coat bitumen	Gal.	0.50	5,848	2,924.00
6	Asphalt Cement (5.26% added)	Ton	81.00	2,215.03	179,417.43
7	Mobilization Cost	Lump Sum	7,500.00	Lump Sum	7,500.00
8	Wedge Shouldering, after paving	Mile	2,000.00	10.065	20,130.00
9	County furnished gravel (331/3%)	Ton	2.30	13,303	30,596.90
	TOTAL COST OF RECYCLING PROJECT =				$729,013.57

ESTIMATED VIRGIN MATERIALS COST

Item No.	Item	Unit	Unit Price	Quantity	Amount
1	Construct 4'-6' shoulders	Mile	31,000.00	10.065	312,015.00
2	Base, Asphaltic Concrete, 4"	Ton	8.00*	30,195	241,560.00
3	Primer or tack-coat bitumen	Gal.	0.50	5,196	2,598.00
4	Additional Right of Way	Mile	10,000.00	10.065	100,650.00
5	Asphalt Cement (7.5%)	Ton	81.00	2,259	182,979.00
6	Wedge shouldering, after paving	Mile	2,000.00	10.065	20,130.00
7	Mobilization	Lump Sum	7,500.00	Lump Sum	7,500.00
	TOTAL ESTIMATED COST ALL VIRGIN MATERIAL =				$867,432.00

*Based on similar 1975 bid - all aggregates and materials furnished by contractor.

TOTAL SAVINGS = $138,418.43 or $13,752.45 per mile

ENTROPY
ENVIRONMENTALISTS, INC.

SPECIALISTS IN
SOURCE
SAMPLING

SOURCE SAMPLING REPORT

EXPERIMENTAL ASPHALT CONCRETE
RECYCLING PLANT IN IOWA

68-01-3172

OCTOBER 1976

P. O. Box 12291, Research Triangle Park, North Carolina 27709
Phone 919-781-3550

REPORT CERTIFICATION

The sampling and analysis performed for this report was carried out under my direction and supervision.

Date December 15, 1976

Signature *Emil W. Stewart*
Emil W. Stewart

I have reviewed all testing details and results in this test report and hereby certify that the test report is authentic and accurate.

Date December 15, 1976

Signature *Walter Smith*
Walter Smith

TABLE OF CONTENTS

INTRODUCTION

The asphalt concrete industry and state transportation agencies are looking at the feasibility of recycling old asphalt pavement in modified drum-mix drier plants. One such experimental plant located in Kosuth County, Iowa, has concerned the Iowa Department of Environmental Quality, due to previous observation of excessive visible emissions from a similarly operated plant. EPA Region VII was requested by the Iowa DEQ for technical assistance to determine if the plant was complying with the state air pollution regulations.

As part of its continuing study of new asphalt concrete technology trends and their impact on the Federal New Source Performance Standards, the Division of Stationary Source Enforcement of EPA agreed to provide assistance to the Iowa DEQ.

Source sampling was performed at the Everds Brothers, Inc. asphalt recycling plant located near Titonka, Iowa, on two separate occasions, under three different plant operating conditions.

Briefly, the first two conditions involved changes in the location of the recycled material injection. Only one set of simultaneous particulate tests at the inlet and outlet of the wet scrubber control equipment was made on September 29, 1976, because of problems encountered with the conveyor equipment used to introduce the recycled material midway in the drier. Three sets of simultaneous inlet-outlet particulate tests and one set of particle sizing tests were made on September 30 and October

1, 1976 (after process changes were made to feed all of the recycled asphalt material into the drier at the elevated end, along with the virgin material). In addition to the particulate tests, air samples before and after the scrubber were taken for a hydrocarbon analysis.

The last condition constituted a change in the type and rate of production of asphalt mix produced and an increase in the rotary drier's angle of elevation. The asphalt mix was changed from 66% recycled/34% gravel at a production rate of 185 to 204 tons per hour to 70% recycled/30% limestone at 245 to 250 tons per hour, while the drier slope was increased from 2° to 2.98° Three particulate tests were run at the separator outlet on October 6, 1976; three venturi-scrubber inlet particulate tests were performed on October 7, 1976 along with a set of inlet-outlet particle sizing tests.

During all the testing, water samples were taken at the scrubber water pump inlet and at the separator water discharge for a water analysis.

Present during the testing were Ronald Kolpa of the Iowa Department of Environmental Quality and Robert Farnham and Lee Binz from Barber-Greene Company, the manufacturers of the plant facility.

The measurements made for stack gas flow rates and particulate emissions were made according to the Iowa Department of Environmental Quality's recommendations and generally followed the U.S. Environmental Protection Agency's requirements. Due to the sampling problem of plugging filters encountered during the previous tests, a modified Method 8 sampling train was used in an attempt to alleviate the problem.

Following sections of this report treat the summary of results, a brief descrition of the process and its operation, and the sampling and analytical procedures used.

SUMMARY OF RESULTS

The results of the particulate testing program are summarized and presented below in Table 1. The values used in computing the averages presented below were reasonably consistent, considering the nature of the process and the control equipment.

Table 1
AVERAGE PARTICULATE CONCENTRATIONS
grains/dscf

Operating Conditions* #	Venturi Inlet EPA 5 Only	Venturi Inlet EPA 5 + Impingers	Test Set #	Separator Outlet EPA 5 Only	Separator Outlet EPA 5 + Impingers	Corresponding Table #'s
1	2.04	2.35	1	0.22	0.31	2-3
2	5.35	5.54	2-4	0.48	0.57	4-5
3	DNA	20.67	1-3	DNA	0.88	6-7

* See "Process Description and Operation" for details

Tables 2-7, as noted above, are summations of the individual test results from the particulate testing. Since a modified Method 8 sampling train was used in making the inlet-outlet tests during the third operating condition, no "EPA 5"results are available - a Method 8 train eliminates the filter between the probe and the water-filled impingers. For this reason, only "EPA + Impinger" results are presented in Tables 6 and 7, and in Table 1, under condition 3. Flow rate determinations for the scrubber outlet stack appear to be higher than real based on the calculated venturi-scrubber inlet flow rate. The higher value is probably due to non-parallel flow in the stack (most probably tangential). Generally, the results would be lower than real due to sampling over isokinetically; however, due to the extremely small particle sizes as noted below, there probably was a negligible effect.

Results of the particle sizing tests on conditions two and three are given in Tables 8-11; no particle sizings were made under the first operating condition of the plant. During the second and third conditions, the aerodynamic diameter of 50% of the particles was less than the following sizes - second condition: inlet, 5.5 microns; outlet, 0.43 microns; third condition: inlet, 99% greater than 10 microns; outlet,7.1 microns.

Analysis for gaseous hydrocarbons on the air samples taken from the venturi inlet and scrubber outlet during condition two resulted in values for the inlet only. The outlet bag samples developed a leak during shipment, resulting in dilutions and lower figures. By assuming the amount of carbon monoxide to be constant from the venturi inlet to the scrubber outlet, the total hydrocarbon content reported at the outlet was recalculated and found to be approximately the same as at the inlet. The inlet data was reported as follows: total hydrocarbons, 468 parts per million; methane, 18 parts per million; carbon monoxide, 2065 parts per million. On the total hydrocarbon measurement, an apparently very heavy hydrocarbon was present since the relative decay of a portion of the total was very slow. If heated lines were used to bring the sample from the stack directly into the instrument, the total hydrocarbon results might have been much higher.

Analysis of the water samples resulted in the values reported in Table 12. Because the analytical method used in determining the dissolved solids is designed for concentrations lower than those found, the results for the dissolved solids are questionable.

No visible emissions data was taken because of the nature of the steam dissipation in the plume. In general, however, the opacity was noted to be approximately 25-30%.

Table 2

SUMMARY OF RESULTS, PARTICULATE EMISSIONS

VENTURI INLET DUCT

RUN NUMBER	1
DATE	9/29/76
STACK TEMPERATURE, DEG. F	366.
PERCENT EXCESS AIR	152.
PERCENT ISOKINETIC	108.4
STACK FLOW RATE SCFM* DRY	32119.
STACK FLOW RATE ACFM, WET	67663.
VOLUME OF GAS SAMPLED SCF* DRY	65.5
PARTICULATES, EPA METHOD 5:	
CATCH - MGRAMS	8658.8
CONCENTRATION - GR/DSCF*	2.036
EMISSION RATE - LBS/HR	560.41
PARTICULATES, EPA METHOD 5 + IMPINGERS:	
CATCH - MGRAMS	10007.3
CONCENTRATION - GR/DSCF*	2.353
EMISSION RATE - LBS/HR	647.69

* 68 DEG F, 29.92 IN. HG

Table 3

SUMMARY OF RESULTS, PARTICULATE EMISSIONS

VENTURI-SCRUBBER OUTLET STACK

RUN NUMBER	1
DATE	9/29/76
STACK TEMPERATURE, DEG. F	144.
PERCENT EXCESS AIR	185.
PERCENT ISOKINETIC	103.1
STACK FLOW RATE SCFM* DRY	69301.
STACK FLOW RATE ACFM, WET	102545.
VOLUME OF GAS SAMPLED SCF* DRY	82.8
PARTICULATES, EPA METHOD 5:	
CATCH - MGRAMS	1155.9
CONCENTRATION - GR/DSCF*	0.215
EMISSION RATE - LBS/HR	127.72
PARTICULATES, EPA METHOD 5 + IMPINGERS:	
CATCH - MGRAMS	1680.1
CONCENTRATION - GR/DSCF*	0.313
EMISSION RATE - LBS/HR	185.64

* 68 DEG F, 29.92 IN. HG

SUMMARY OF RESULTS, PARTICULATE EMISSIONS

VENTURI INLET DUCT

RUN NUMBER	2	3	4
DATE	9/30/76	9/30/76	10/ 1/76
STACK TEMPERATURE, DEG. F	364.	366.	382.
PERCENT EXCESS AIR	146.	146.	146.
PERCENT ISOKINETIC	106.5	97.6	105.4
STACK FLOW RATE SCFM* DRY	31870.	30831.	29797.
STACK FLOW RATE ACFM,WET	69279.	65192.	67057.
VOLUME OF GAS SAMPLED SCF* DRY	61.2	57.5	60.1
PARTICULATES, EPA METHOD 5:			
CATCH - MGRAMS	21429.3	21598.5	19022.1
CONCENTRATION - GR/DSCF*	5.388	5.784	4.878
EMISSION RATE - LBS/HR	1471.69	1528.27	1245.67
PARTICULATES, EPA METHOD 5 + IMPINGERS:			
CATCH - MGRAMS	22257.6	22347.4	19694.7
CONCENTRATION - GR/DSCF*	5.597	5.985	5.051
EMISSION RATE - LBS/HR	1528.58	1581.26	1289.71

* 68 DEG F, 29.92 IN. HG

SUMMARY OF RESULTS, PARTICULATE EMISSIONS

VENTURI-SCRUBBER OUTLET STACK

RUN NUMBER	2	3	4
DATE	9/30/76	9/30/76	10/ 1/76
STACK TEMPERATURE, DEG. F	146.	145.	147.
PERCENT EXCESS AIR	146.	146.	146.
PERCENT ISOKINETIC	101.2	103.9	106.4
STACK FLOW RATE SCFM* DRY	75389.	73062.	71668.
STACK FLOW RATE ACFM, WET	121156.	113166.	114850.
VOLUME OF GAS SAMPLED SCF* DRY	49.4	48.7	49.4
PARTICULATES, EPA METHOD 5:			
CATCH - MGRAMS	1667.9	1617.2	1286.0
CONCENTRATION - GR/DSCF*	0.520	0.512	0.401
EMISSION RATE - LBS/HR	335.75	320.30	246.22
PARTICULATES, EPA METHOD 5 + IMPINGERS:			
CATCH - MGRAMS	2066.4	1903.5	1531.4
CONCENTRATION - GR/DSCF*	0.644	0.602	0.477
EMISSION RATE - LBS/HR	415.96	377.00	293.21

* 68 DEG F, 29.92 IN. HG

Table 6

SUMMARY OF RESULTS,PARTICULATE EMISSIONS

VENTURI INLET DUCT

RUN NUMBER	1	2	3
DATE	10/ 7/76	10/ 7/76	10/ 7/76
STACK TEMPERATURE, DEG. F	410.	410.	425.
PERCENT EXCESS AIR	138.	138.	138.
PERCENT ISOKINETIC	109.3	105.9	107.2
STACK FLOW RATE SCFM* DRY	30029.	32324.	30422.
STACK FLOW RATE ACFM,WET	68482.	72455.	72792.
VOLUME OF GAS SAMPLED SCF* DRY	40.8	38.6	36.8
PARTICULATES, EPA METHOD 5 + IMPINGERS:			
CATCH - MGRAMS	59145.3	48014.1	49067.9
CONCENTRATION - GR/DSCF*	22.305	19.158	20.541
EMISSION RATE - LBS/HR	5740.18	5306.97	5355.24

* 68 DEG F, 29.92 IN. HG

Table 7

SUMMARY OF RESULTS, PARTICULATE EMISSIONS

VENTURI-SCRUBBER OUTLET STACK

RUN NUMBER	1	2	3
DATE	10/ 6/76	10/ 6/76	10/ 6/76
STACK TEMPERATURE, DEG. F	151.	153.	151.
PERCENT EXCESS AIR	130.	133.	146.
PERCENT ISOKINETIC	107.9	109.8	101.2
STACK FLOW RATE SCFM* DRY	68084.	66322.	65319.
STACK FLOW RATE ACFM, WET	109586.	110040.	105097.
VOLUME OF GAS SAMPLED SCF* DRY	47.8	29.7	26.9
PARTICULATES, EPA METHOD 5:			
CATCH - MGRAMS	0.0	0.0	0.0
CONCENTRATION - GR/DSCF*	0.000	0.000	0.000
EMISSION RATE - LBS/HR	0.00	0.00	0.00
PARTICULATES, EPA METHOD 5 + IMPINGERS:			
CATCH - MGRAMS	2963.6	1617.5	1487.0
CONCENTRATION - GR/DSCF*	0.954	0.840	0.851
EMISSION RATE - LBS/HR	556.53	477.31	476.19

* 68 DEG F, 29.92 IN. HG

Table 8

Summary of Results

Particulate Size Analysis

Condition 2 Inlet

Physical Particle Size, Microns	Aerodynamic Particle Size, Microns	Percent Less Than Stated Size, Weight Basis
6.85	8.15	67.4
4.30	5.12	47.4
2.83	3.37	23.6
1.97	2.34	7.4
1.24	1.48	3.6
0.63	0.75	3.1
0.38	0.45	2.8
0.25	0.30	2.5

Sampling Conditions

Location: Point A-4

Sampling Time: 5 min.

Sample Volume: 6.89 acf

Stack Temperature: 370°F

Date: 10-1-76

Table 9

Summary of Results

Particulate Size Analysis

Condition 2 Outlet

Physical Particle Size, Microns	Aerodynamic Particle Size, Microns	Percent Less Than Stated Size, Weight Basis
10.40	9.77	99.9
6.52	6.15	95.9
4.34	4.09	92.9
3.01	2.84	91.0
1.90	1.79	87.2
0.98	0.92	79.6
0.59	0.55	69.2
0.39	0.37	40.4

Sampling Conditions

Location: Point B

Sampling Time: 9 min

Sample Volume: 8.60 acf

Stack Temperature: 150°F

Date: 10-1-76

Table 10

Summary of Results

Particulate Size Analysis

Condition 3 Inlet

Physical Particle Size, Microns	Aerodynamic Particle Size, Microns	Percent Less Than Stated Size, Weight Basis
9.02	10.3	1.4
5.59	6.38	-
3.71	4.24	-
2.58	2.95	-
1.64	1.87	-
0.84	0.96	1.3
0.50	0.57	1.1
0.34	0.38	0.6

Sampling Conditions

Location: Point E-7

Sampling Time: 15 min

Sample Volume: 13.37 acf

Stack Temperature: 463°F

Date: 10-7-76

Table 11

Summary of Results

Particulate Size Analysis

Condition 3 Outlet

Physical Particle Size, Microns	Aerodynamic Particle Size, Microns	Percent Less Than Stated Size, Weight Basis
14.9	14.1	81.9
9.32	8.79	60.8
6.23	5.88	42.5
4.34	4.09	38.1
2.72	2.57	29.0
1.41	1.33	22.7
0.86	0.81	21.8
0.59	0.55	20.4

Sampling Conditions

Location: Point D-5

Sampling Time: 15 min

Sample Volume: 7.09 acf

Stack Temperature: 151°F

Date: 10-7-76

Table 12

WATER ANALYSIS RESULTS

DATE	PART. TEST #	SAMPLE IDENT. A-INLET B-OUTLET	SOLIDS* TOTAL (mg/L)	SUSPENDED (mg/L)	DISSOLVED (mg/L)	OIL & GREASE (mg/L)
9-29	1	1A	2393	152	2241	94
		1B	2932	462	2470	457
9-30	2	2A	2629	152	2477	126
		2B	4384	1232	3152	360
	3	3A	2577	134	2443	103
		3B	4803	620	4183	301
10-1	4	4A	2791	104	2687	92
		4B	4441	964	3477	252
10-6	5	5A	4973	152	4821	33
		5B	13020	11332	1866	621
	6	6A	4929	150	4779	66
		6B	11442	6236	5206	476
10-7	7	7A	4425	142	4283	44
		7B	13302	12632	670	813
	8	8A	4149	224	3925	35
		8B	14553	10248	4305	733

*Total solids figures are accurate. Dissolved solids figures are questionable, since the method for dissolved solids is designed for much lower concentrations.

PROCESS DESCRIPTION AND OPERATION

The Everds Brothers, Inc. plant located near Titonka, Iowa, is a modified Barber-Greene continuous drum-mix asphalt plant. The modifications allow the plant to manufacture asphalt using recycled asphalt pavement removed from existing road surfaces.

In general, the continuous drum-mix plant operates in the following manner: coarse and fine aggregate is proportionately released from feed hoppers (according to the type of road mix being produced) onto a conveyor which drops the aggregate into the elevated end of the rotating drier. The aggregate is mixed, dried, and heated so that when the asphalt is introduced into the drier, the desired asphalt mix is produced. The hot asphalt mix leaves the drier and is mechanically elevated to holding bins for storage until released into trucks for hauling to the job site.

Potential emissions consist of stone dust from the aggregate and hydrocarbons from the asphalt introduced in the drier. When recycled asphalt pavement is used, a greater amount of hydrocarbons in the form of pulverized asphalt is introduced, thereby increasing the possibility of larger potential emissions. As shown in Figure 1, control equipment consists of a venturi-scrubber system with a separator stack. During the testing the normal pressure drop across the venturi was 14 to 15 inches of water, with the scrubber using from 450 to 485 gallons of water per minute.

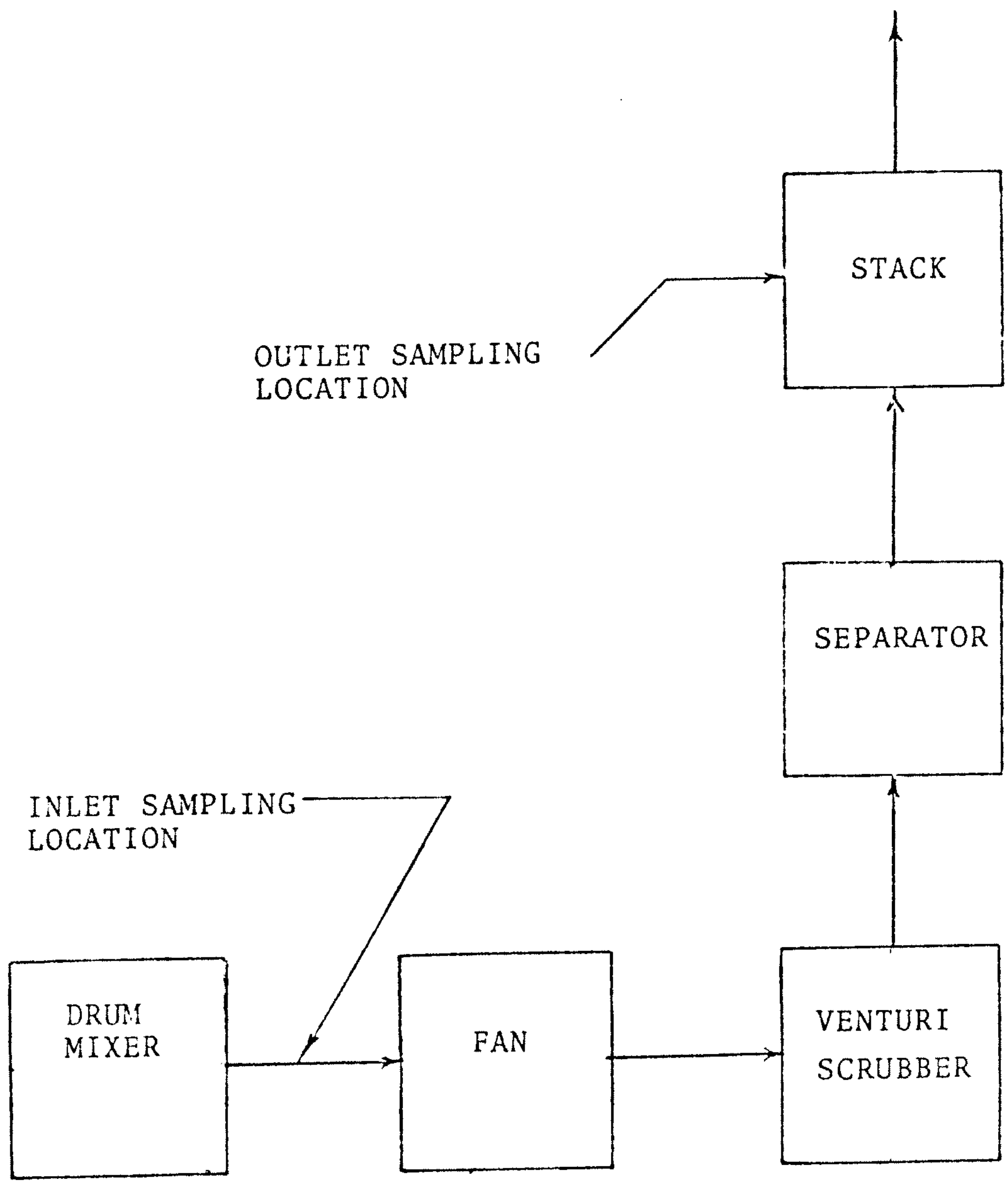


FIGURE 1. PROCESS AIR FLOW SCHEMATIC & SAMPLING LOCATIONS

At the beginning of the testing program, the fine aggregate-pulverized recycled asphalt pavement - was introduced into the drier just prior to the asphalt injection location. The asphalt mix produced consisted of 66% recycled asphalt and 34% gravel, and at a rate of 185 tons per hour. Due to problems with the recycled material injection system, the fines injection at the midpoint of the drier had to be abandoned and replaced with the introduction of the recycled material in the normal manner, i.e., with the coarse aggregate, by conveyor. The original method constituted condition one, while the subsequent system became condition two, with a production rate of 185 to 205 tons per hour.

After a partial analysis of the results from the first series of tests the plant mode of operations was changed substantially by Everd Brothers in an attempt to clean up the plume. The slope of the drum mixer was increased from 2 to 2.98°. Aggregate mix was changed to 70% recycled asphalt and 30% limestone with a rate of production of 245 to 250 tons per hour. This condition of operation was designated condition three. Following is a table cataloging the parameters for each of the three conditions.

Table 13

PLANT OPERATING PARAMETERS

Condition #	Drum-Mixer Slope, (deg)	Aggregate Mix & Percentages Size %	Size %	Production (tons/hr)	Venturi Pressure Drop (in H_2O)	Scrubber Water Feed, (gal/min)
1	2.0	recycled-66	gravel-34	185	14½	476
2	2.0	recycled-66	gravel-34	185-205	12-15½	474
3	3.0	recycled-70	limestone-30	245-250	13-15	453

SAMPLING AND ANALYTICAL PROCEDURES

All of the sampling and analytical procedures used were those recommended by the U.S. Environmental Protection Agency or the Iowa Department of Environmental Quality.

In accordance wtih Method 1, the number of points to be sampled was determined by the distance of the traverse axes from the nearest gas stream disturbances. The location of each sampling point was also found using Method 1 guidelines.

The venturi-scrubber inlet testing was performed on the ducting between the drier and the fan. As shown in Figure 2, the duct cross section was divided into 48 equal areas, with eight sampling points on each of the six traverse axes. Due to the duct dimensions, the access holes were staggered as illus trated in Figure 2, and labeled A through F. While testing conditions one and two, each point was sampled for two minutes each for a total testing time of 96 minutes for each run. For condition three, each point was only sampled for one and a quarter minutes, giving a total testing time of 60 minutes for each run.

For the outlet testing at the separator stack, the stack cross section was divided into 48 equal areas. Four ports labeled A through D as shown in Figure 3 provided access to the traverse axes. Each of the points was sampled for two minutes for a testing time of 96 minutes for each run performed on conditions one and two. Condition three tests sampled each point for only

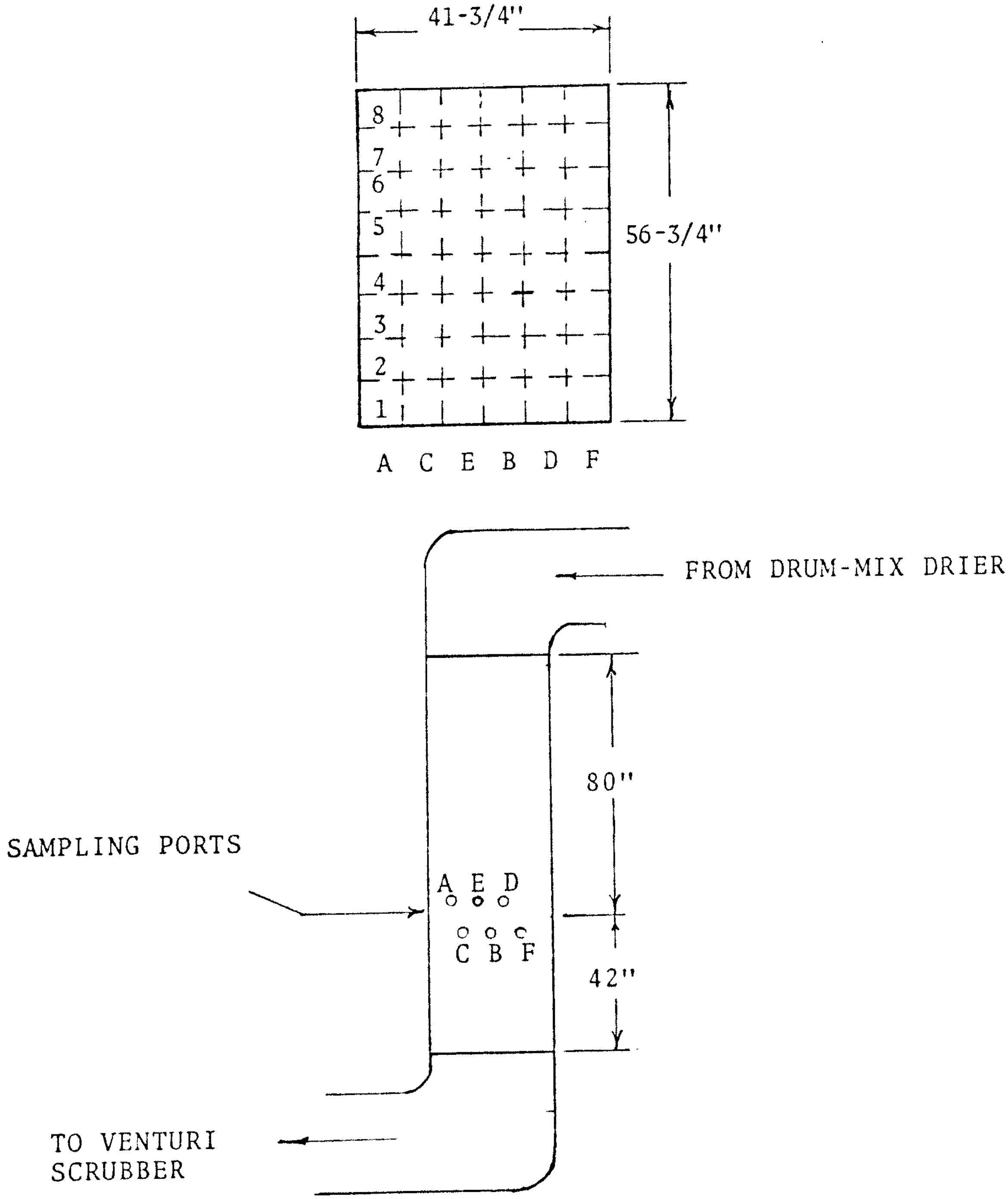


FIGURE 2. VENTURI INLET DUCT DIMENSIONS
& SAMPLING POINT LOCATIONS

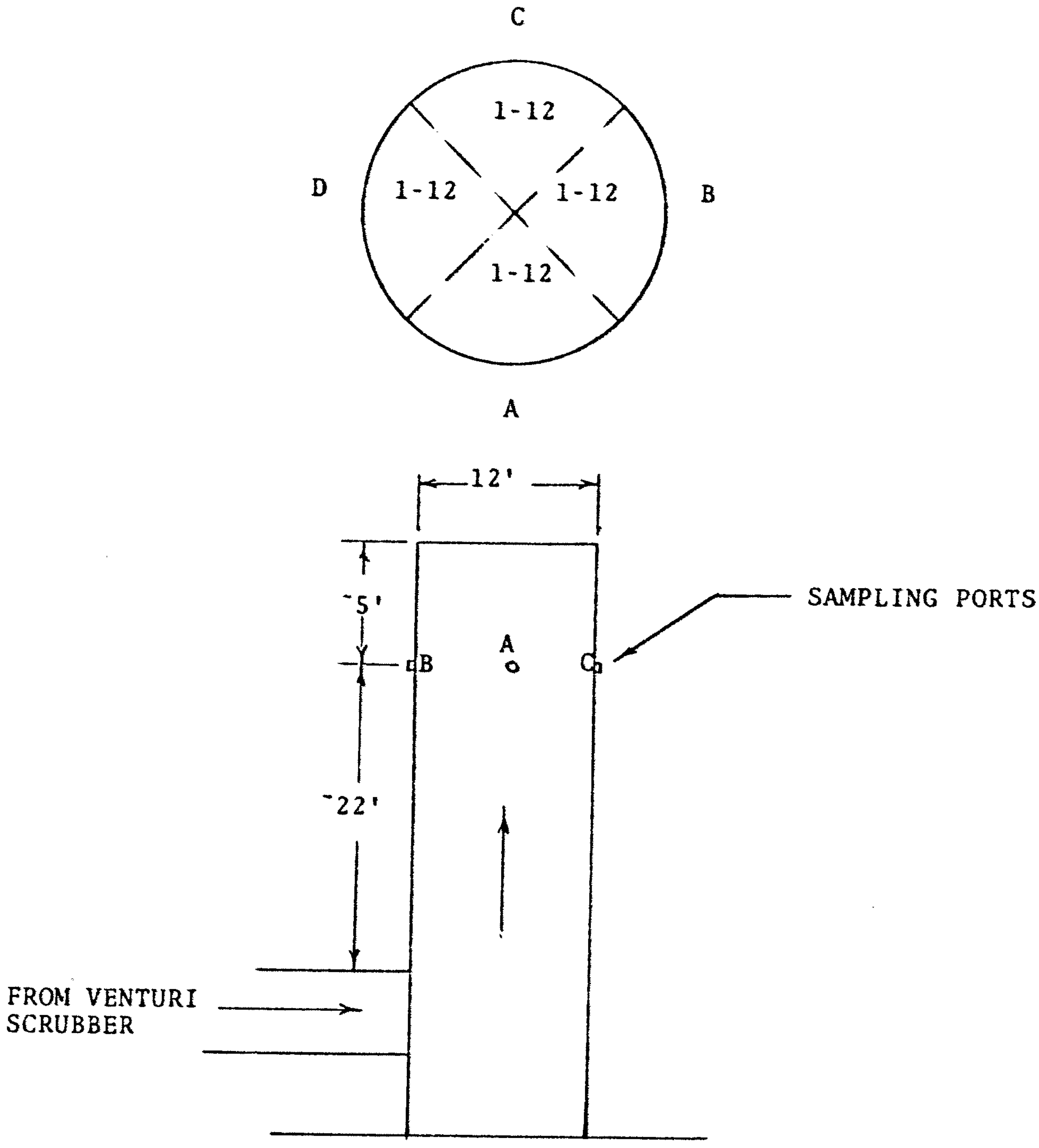


FIGURE 3. SCRUBBER OUTLET STACK DIMENSIONS & SAMPLING POINT LOCATIONS

one and a quarter minutes for a run time of 60 minutes.

Velocity data was taken following Method 2, while Method 3 was used in determining the molecular weight, excess air, and composition of the stack gases. In general, Method 5 as outlined in the Federal Register provided the sampling and analytical procedures that were followed; however, the analysis also included the condensibles found in the impinger water. For condition three tests, a Method 8 sampling train configuration with the filter placed between the third (dry) impinger and the fourth (silica gel) impinger was used. Paritcle sizing was performed using an Andersen Head Impactor and a Method 5 sampling train.

On the first test performed on condition two at the outlet (labeled "outlet #2), the frit material in the filter holder broke on the last point in the test. There seemed to be negligible particulate carryover, as most of the particulate was adhering to the filter and was not in a loose, dry state in the filter holder chamber.

All equipment used was manufactured by Research Appliance Company, Nutech Corporation, or Entropy Environmentalists, Inc.

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