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Sec 1.3
Ref. 12
4176

Air Pollution:

What
Will
Be
Required
Fuel Oil Help?

Decomposition
of sulfur
dioxide
effect on oil
fouling

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SEVERE restrictions are expected on emission of sulfur oxides from stationary combustion sources in many areas in the relatively near future. These restrictions will be based on both ambient SO_2 concentrations, by the levels proposed in the criteria published by the Dept. of Health, Education and Welfare in 1968 and in the revised criteria to be issued shortly. They will apply both to power generation, which accounts for more than half (52%) of the total SO_2 emitted, and to commercial and industrial combustion which accounts for about 24%. Emissions from the commercial and industrial boilers are felt by some people to have a greater influence on ambient SO_2 concentration than those from power stations because their stacks are so much shorter.

A little less than half of the SO_2 from commercial and industrial combustion can be attributed to residual fuel oil with essentially all of the rest coming from coal. A major portion of this residual fuel market is in large urban areas on the East or West Coasts of the United States where fuel can be delivered by tanker. In many of these areas, sulfur regulations have already gone into effect or will shortly be imposed.

Thus, a large part of the residual fuel oil market will soon have to be supplied low sulfur fuel oil. Suppliers are currently making arrangements to meet this demand with either natural low sulfur fuel oil or with desulfurized fuel oil. Either of these products will be different from currently available fuel oil in several respects. However, only minor alterations to the design of new or existing installations will be required to handle the low sulfur fuels.

FUELS AND DEW POINT

The obvious effect of reducing fuel oil sulfur content is, of course, the corresponding reduction in sulfur oxide content of the flue gas. The reduction in sulfur dioxide content will

be essentially proportional to the reduction in fuel sulfur content, since about 98% of the sulfur in fuel oil is emitted as SO_2 . However, sulfur trioxide, SO_3 , reduction will be a side benefit. The presence of even small amounts of SO_3 in the gas (70 to 80 ppm) causes sulfuric acid to precipitate even at temperatures above 300 F. This can cause corrosion in the cold portion of the boiler or the stack or result in the emission of highly acidic solid particles which damage paint and fabrics. The amount and benefit of SO_3 reduction will depend upon the sulfur level of the low sulfur fuel oil and the operating conditions of the boiler. Acid dew point of the flue gas as a function of fuel oil sulfur content and excess air level is shown in Fig. 1. The absolute level of dew point is to a certain extent a function of the individual boiler and load conditions, so this figure must be considered somewhat qualitative. The dew points shown are typical of the levels encountered in large power boilers but are similar to those encountered in industrial boilers. At relatively high excess air levels, 15 to 25%, dew point is in the range of 300 F with 2.5 to 3% S fuel oil. With a 1% S fuel oil, there is a relatively minor reduction of dew point to about 250 F. Only when S content is reduced below 0.5% is there a marked reduction in dew point to less than 200 F.

With moderately low excess air, 3 to 5%, the dew point is in the range of 200 to 250 F with fuels of 2.5% S and drops to 150 to 200 F at 1% S or less. At very low excess air, 1%, dew point is about 150 F regardless of fuel oil sulfur content.

Thus, although the lower sulfur fuel oil will tend to give a lower flue gas dew point, operation with a minimum of excess air will still be necessary. High levels of dew point and solid emission and cold end corrosion will not be gone as severe, but for all except the lowest sulfur fuels, moderately low excess air will be beneficial.

NATURAL LOW SULFUR FUEL OIL

Low sulfur fuel oils will be made either from low sulfur

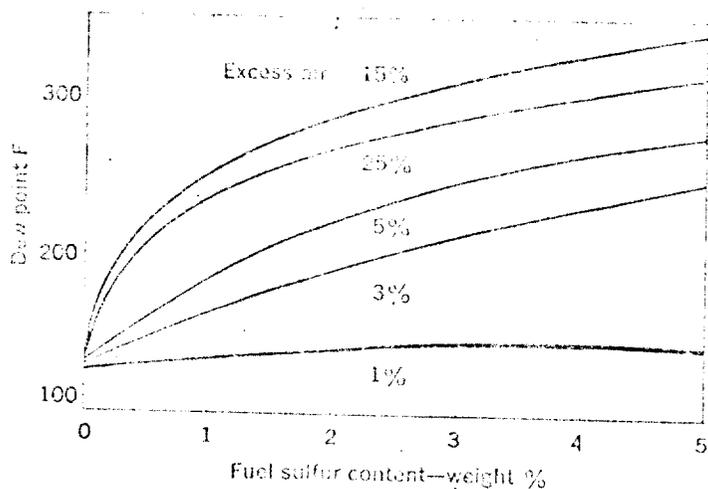


Fig. 1. Effect of fuel sulfur content and excess air on flue gas acid dew point.

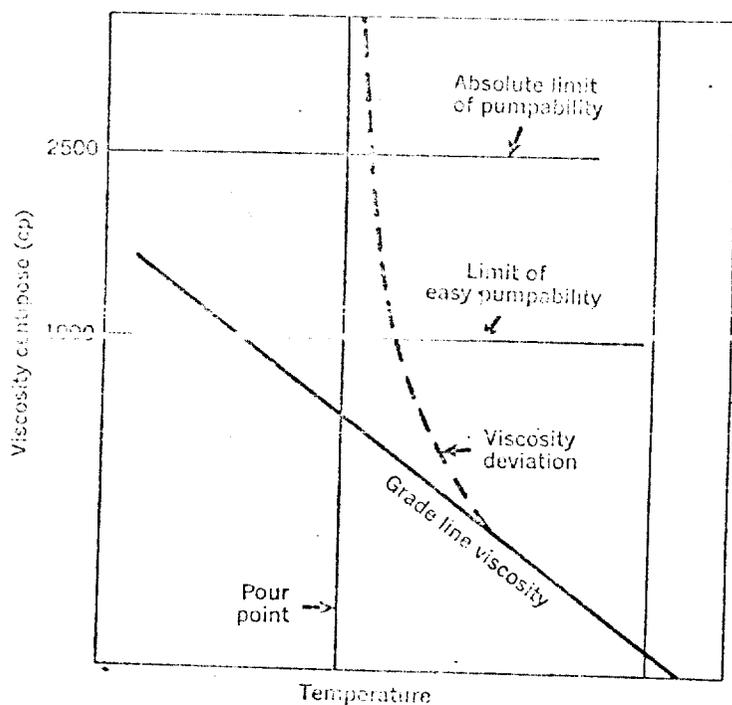


Fig. 2. Deviation of viscosity from grade line above pour point.

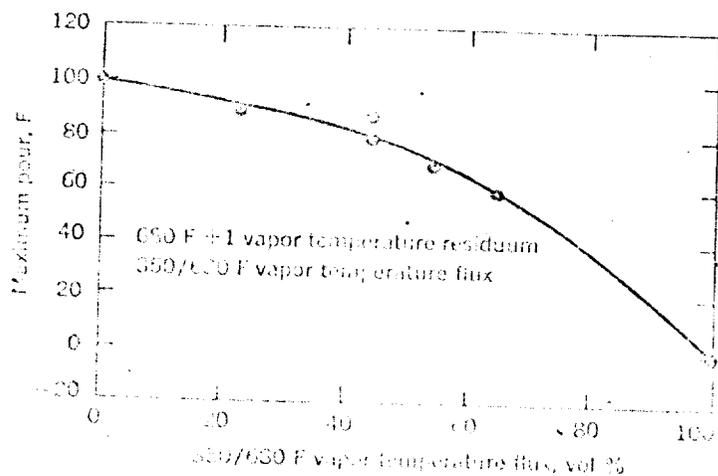


Fig. 3. Pour point of blends of North African residuum and distillate flux.

crudes or by desulfurization of components made from higher sulfur crudes. The major source of natural low sulfur fuel oil will be the North African crudes, principally from Libya and Nigeria, and some Far Eastern crude from Sumatra. Fuels made from these crudes will meet even very low S regulations calling for 0.5% S or less. These crudes are highly paraffinic, which means that fuel oils produced from them are quite waxy and must be kept hot during handling because of their high pour points. These fuels will solidify at temperatures as high as 105 to 110 F. A rapid increase in viscosity, which occurs 10 to 15 F above the pour point, compounds the problem. The viscosity increase can be attributed to wax which has precipitated and started to form gel structures. Although these structures are not rigid enough to prevent all movement, they interfere with free flow of the oil. An installation must be designed to keep fuel temperature at least 15 F above pour point to avoid pumping difficulties, particularly where suction lines are long.

The viscosity increase is illustrated in Fig. 2. The solid line is the grade line viscosity which can be extrapolated from viscosity measurements at high temperatures. Variation of grade line viscosity with temperature is the same for waxy and non-waxy fuel oils. The dotted line shows how viscosity deviates from the grade line just above the pour point. The horizontal lines represent viscosities of 1000 and 2500 centipoises (cp). These have been designated as the limit of easy pumpability, and the absolute limit of pumpability, respectively. Above 1000 cp, pumping difficulty can be expected and above 2500 cp a major loss in pump capacity is normally encountered.

To avoid difficulty, heated tanks and suction lines are needed to handle high pour (105 to 110 F) fuel oil. Temperatures of 120 to 130 F must be maintained in all parts of the system to avoid pumping problems. Suction lines are particularly critical because of the low ΔP available in them. Normally, they need to be insulated and heated for satisfactory operation. A possible alternative is to maintain continuous circulation through a preheater and back to storage. However, with this system, any interruption of the circulation can result in solidification in the lines making it extremely difficult to re-establish circulation.

The heaters in fuel storage tanks must cover the entire bottom surface of the tank. Suction heaters are not adequate, since portions of the fuel may solidify in the tank and not be able to slump to suction. Tank heaters must be installed very close to the bottom of the tanks so that the contents of the tank can be melted if it should solidify. Any fuel below the level of the heater is very difficult to melt once it has solidified. Fill lines must drain completely into the tank or be blown clear after each fill. Any accumulation of fuel in low spots in the fill line will solidify and interfere with the next fill. Vent lines must be heated to prevent plugging by fuel which splashes into them and may solidify.

In some cases, blends of natural low sulfur fuel oils with other higher sulfur fuel oils will be adequate to meet more moderate sulfur regulations. The fuel oil fractions of North African crudes contain about 0.1% S. Thus, significant amounts of higher sulfur fuel oils can be added to them to make blends which meet regulations calling for 1 to 2% S. These blends will have lower pour points than the straight North African fuel oil, although the reduction is not necessarily proportional to the dilution. For example, a 75:25 blend of 105 F pour North African fuel oil and a

200 ppm Vanadium in fuel oil for a sulfur content of 1% and a pour point of 90 to 95 F. If pour blended linearly, the blend would be expected to have a 50 F pour point. Even so, the fuel oil can be handled at temperatures 10 to 15 F lower than the straight North African fuel. This tends to reduce the heating requirements somewhat although heated lines and tanks are still required. Many of the large industrial installations would be able to handle this fuel oil with no additional facilities required.

Where fuel oil will be handled or stored in facilities which are not capable of maintaining high temperatures, distillate flux will have to be used to achieve lower pour point. Since the flux is normally commercial similar to home heating oil which is low in sulfur content, its use permits a reduction in the percentage of North African component in the blend while still meeting the sulfur target. This lowers pour. However, very substantial dilutions are usually necessary to achieve a significant reduction in pour. Fig. 3 shows the effect of diluting a North African residual with distillate flux. A major pour reduction is not achieved until the blend contains large amounts of distillate.

Fuel oils which are blended of waxy and non-waxy residuals plus distillate flux will frequently exhibit unusual pour behavior. When they are freshly blended, the wax will prevent pouring or pumping at a given temperature. After they have been aged for a period of time, this will happen at a higher temperature—sometimes as much as 40 to 50 F higher. This pour reversion is the result of the interaction of wax and asphaltenes from the various components of the blend. Asphaltenes are highly condensed aromatics of very high molecular weight which are solidified in nature. They occur in higher concentrations in non-waxy fuels than in waxy ones. When a blend containing wax and asphaltenes cools initially, asphaltenes are incorporated into the wax crystals, limiting their growth and hindering agglomeration to form rigid structures. As a result, the fuel remains fluid until it reaches a lower temperature than it would in the absence of the asphaltenes. However, when the fuel oil is stored, some recrystallization occurs. The lighter waxes dissolve and reprecipitate in new crystals. The heavier waxes remain solid and tie up the asphaltenes, which then cannot modify the structure of the recrystallized wax. The new crystals prevent flow at a higher temperature. Since the heavy wax in residual fuels may not dissolve completely below 160 to 180 F, storage at any lower temperature can cause reversion. The tendency toward reversion is very minor in waxy fuels which have high pour points under any circumstances. It is moderate in blends of waxy and non-waxy fuels of high viscosity and becomes more pronounced in lower viscosity fuels containing distillate flux in addition to the waxy and non-waxy residuals.

A normal pour point test (ASTM D 97) does not predict this phenomenon adequately. Therefore, a special test, called the flow point, was developed. In this test, a sample is put through a series of temperature cycles to induce maximum reversion before its pour point is measured. The method developed by the British Admiralty (known as Admiralty Method VII) although it is time-consuming and tedious to perform and may be conservative, it is the only way to predict flow behavior after storage. Specifications on low sulfur fuels should require that a flow point rather than an upper pour should be met whenever the fuel must be capable of easy movement at temperatures below 60 F. Where handling

temperatures are in the range of 90 F or higher, pour point should be adequate.

One obvious result of adding flux will be that the fuel oil will have a considerably lower viscosity and a higher API (American Petroleum Institute) gravity. The viscosity of fuel oils used where No. 6 fuel is currently used may be almost as low as that of current No. 4 fuel. As a result, preheat temperatures can be reduced without impairing atomization. Some adjustment may be required in metering devices to compensate for the lower viscosity. In some cases, existing pumps may not be satisfactory with the low viscosity fuel oil, either because they will not develop adequate head or because they will wear too rapidly.

In general, as API gravity goes up, i.e., the density of the fuel decreases, the heat of combustion or heat content per gal will decrease. Thus, the higher API gravity fuel oil will tend to have fewer Btu/gal. This will be offset somewhat by the lower sulfur content because sulfur has a lower heat of combustion than hydrocarbons. For example, a 3% sulfur fuel of 24 deg API gravity would have a gross heat content of about 142,000 Btu/gal compared with 147,600 Btu/gal in a conventional 15 deg API fuel also containing 3% sulfur. However, if sulfur content of the 24 deg API fuel is cut to 1%, the gross heat content increases to 144,300 Btu/gal, and at 0.3% S it would be 145,100 Btu/gal. Thus, the actual decrease in heat content would be only 1.5 to 2% instead of the 4 to 5% which might be expected on the basis of the change in gravity alone.

One of the major benefits of the low sulfur fuel oils is that they will contain substantially lower amounts of ash and asphaltenes than typical current fuel oils. North African residuals are low in both of these materials, and, of course, distillate flux contains neither.

The effect of the reduction in fuel oil ash content will be a reduction in slag deposits on superheater tubes or other parts of the furnace. A typical Venezuelan fuel has an ash content approaching 0.1% and a vanadium content of 250 to 300 ppm. However, a fuel oil made from North African crude would contain only 0.005% ash and 10 ppm vanadium. A 1% S blend of North African and Venezuelan fuel oils will have about 0.04% ash and 80 to 90 ppm vanadium. Generally, the rate of slagging on high temperature superheater tubes is controlled by the ash and vanadium contents of the fuel oil. The decreased deposits which result from using low sulfur fuel would reduce downtime for slag clean-out or permit a substantial decrease in additive requirements where magnesium oxide type additives are used. These additives are sometimes used in very large boilers to control superheater corrosion.

The lower asphaltene content of the low S fuels will decrease the weight of carbonaceous particles emitted from the flame. These particles are the unburned residue of fuel droplets and are directly related to asphaltenes in the fuel oil. In some boilers, especially small fin-tube boilers, these particles may collect in the cooler parts of the exchange system or at the base of the stack where eventually they must be cleaned out. This problem as well as the problem of solids emission from the stack will be eased with a low sulfur fuel.

DESULFURIZED FUEL OILS

While some refiners can make low sulfur fuel oils by refining naturally occurring low sulfur crudes, these crudes are not

Table I. Characteristics of Middle East and Venezuelan Crudes and Fuel Oils

	Light Arabian		Kuwait		Tia Juana Med	
	Crude	Fuel Oil	Crude	Fuel Oil	Crude	Fuel Oil
API gravity	34.7	15.5	31.4	15.5	26.5	16.3
Viscosity						
Sulfur, weight %	1.7	3.0	2.5	4.0	1.5	2.0
Pour point, F	-15	+55	-20	+55	-40	+20
SSF at 100 F	44	—	56	—	116	—
SSF at 122 F	—	175	—	175	—	170
Vanadium ppm	13	37	31	61	155	240
Nickel ppm	4	11	7	14	20	31

available in sufficient volume to satisfy the total demand and their location geographically is not generally tributary economically to the areas of greatest demand. For this reason, refiners have had to look for other means to supplement low sulfur fuel production from the more widely available higher sulfur crudes. Fortunately, this can be accomplished by the use of several relatively new processes to desulfurize residuum, vacuum gas oil (VGO), or deasphalted oil (DAO). With the advent of restrictive air pollution regulations, such as those being adopted in New York, New Jersey, and elsewhere, refiners are giving serious consideration to and in some cases proceeding rapidly with the installation of desulfurization facilities. Several companies have already committed extremely large investments to desulfurization plants.

The type of process used, i.e., residuum, VGO, or DAO, will depend upon the type of crude available and the degree of desulfurization desired. The characteristics of the resultant fuel will, in turn, be determined to a large extent by the process used and the final sulfur level.

Residuum desulfurization treats all of the crude boiling above about 650 F by hydrogenation over a catalyst at high temperature and pressure. In the process, metals or ash in the feedstock tend to be deposited on the catalyst causing permanent deactivation. For this reason, residuum desulfurization is normally used only with crudes of moderate metals content such as the Kuwait or Light Arabian shown in Table I.

With crudes of higher metals content, such as the Tia Juana Medium crude from Venezuela in Table I, some form of pretreatment is required to reduce the metals content of the feed to desulfurization. One way to do this is to vacuum distill the fuel oil and desulfurize only the distillate which is known as VGO. This VGO is completely free of metals and can be desulfurized to very low sulfur content. The product from VGO desulfurization is then blended with a portion of the high sulfur, high metals residue from the vacuum distillation to give a product of the desired sulfur content.

Another way to reduce the metals content of the feed to desulfurization is to deasphalt it. A large part of the metals content of the residuum will be removed with the asphalt. The deasphalted fraction may then be desulfurized in a process very similar to residuum desulfurization.

Presently, legislators in the critical pollution areas of New York City and northern New Jersey are proposing standards which eventually may be as low as 0.3% S. For years, the critical Los Angeles-San Joaquin region of California has been restricted to fuel oil with a maximum of 0.5% S. In other regions, for example the Washington, D.C., area, legislation is being proposed which eventually will limit fuel sulfur to a 1.7% maximum. In Japan and Germany,

levels in the neighborhood of 1.7% are in effect with the possibility that lower limits may be set in the future. In areas where there are few sources of pollution, it seems reasonable that sulfur limitations may eventually settle out between 1 and 2%. In the most critical areas like New York and Los Angeles, it can be assumed that 0.3 to 0.5% S restrictions may persist. In general, it appears that there may be two levels of sulfur—very low, in the region of 0.5%, and moderate, in the range of 1.5%.

To reach the lower of these two levels, 0.5% S, quite severe desulfurization conditions will be required regardless of the process used. If it is VGO desulfurization, only a small amount of residuum will be blended back into the desulfurized VGO product. This will mean that 0.5% S fuel oil will be much lower in viscosity than current No. 6 fuel oil. ASTM D 396 sets limits of 45 to 300 Saybolt Seconds Furol (SSF) at 122 F, but most current fuels in the United States are in the range of 150 to 200 SSF at 122 F to maintain constant fuel quality. The desulfurized fuel from the VGO process will probably be in the range of 100 to 150 Saybolt Seconds Universal (SSU) at 100 F (equivalent to about 8 to 10 SSF at 122 F) which is similar to current No. 4 fuel. This low viscosity fuel will also be quite low in ash and asphaltenes, since the VGO contains neither. As a result, problems of superheater deposits and corrosion caused by the vanadium and sodium in the ash, as well as solids emission in the flue gas, should be essentially eliminated.

It is less likely that the very low sulfur fuel will be made by residuum desulfurization. However, if it is, the severity of the operating conditions required may be expected to lower the viscosity of the fuel, but probably not to as low a level as products comprised primarily of VGO. The product will probably be more like a heavy No. 5 oil with a viscosity around 30 SSF at 122 F. Accompanying the reduction in viscosity is an increase in API gravity. At a constant sulfur level, this would mean a reduction in heat content per gal. However, because sulfur is reduced, the heat content remains essentially the same in spite of the gravity change. Metals content and asphaltenes will be reduced somewhat during desulfurization, perhaps of the order of 50%, but again the reduction will not be as drastic as when desulfurized VGO makes up the bulk of the product.

The low viscosity of either the VGO or residual desulfurization products may cause problems in existing pumps due to the large clearances normally allowed for handling the more viscous No. 6 fuel. Thus, some pumps may have to be replaced. The poorer lubricity of the less viscous fuel may also increase wear rate. As with the lower viscosity material low sulfur fuels, some changes in metering devices and preheat temperatures may be required to compensate for the

lower viscosity. The pour properties of the desulfurized fuels will not be greatly changed from those of current fuels from the same source. They should, therefore, present no additional handling problems.

The very low sulfur fuels, 1.5% S, will tend to exhibit changes which are directionally the same as the very low sulfur fuels, but the changes will be less pronounced. The VGO desulfurized product will have more residuum blended back into it, in some cases approaching the total residuum stream. Thus, it will show some reduction in ash, asphaltene, and viscosity, but the changes will not be as drastic as for the low sulfur fuel. Depending upon the sulfur content of the base fuel and of the final fuel oil, the characteristics of the product will range from only slightly different from current No. 6 fuel to a fuel resembling a light or heavy No. 5 fuel.

Similarly, where residuum desulfurization is used for the moderate sulfur level fuel, the operating conditions used will cause a moderate amount of viscosity reduction and metals removal. Thus, this fuel should bear the closest resemblance to undesulfurized fuel or any of the desulfurized products.

OTHER APPLICATIONS OF DESULFURIZED FUEL OILS

As far as fuel applications are concerned, some very interesting changes should become possible as a by-product of desulfurization processing. Aside from the fact that the desulfurized fuels will generally be of improved quality and will be more acceptable from a quality standpoint for critical industrial processes, the industrial gas turbine is one application in which these improved fuels should be eminently more suitable. Present use of bunker fuel in these turbines is limited due to the high ash, vanadium, and sodium contents. In operation, the ash builds up on the turbine blading and eventually decreases capacity output and forces an outage for clean-up. The vanadium and sodium in these deposits may cause intolerable corrosion of the turbine buckets and blades.

The desulfurized fuels at the 0.3 to 0.5% S level may have ash contents as low as 10% of those in today's fuels, perhaps in the neighborhood of 0.01 to 0.02%. There will be similar reductions in vanadium content to less than 50 ppm. This vanadium content will probably not be quite low enough to qualify as a No. 3 gas turbine (GT) fuel (<10 ppm V) under the proposed ASTM specifications for GT fuels. No. 3 GT fuels are those which can be used without additives. Unless great care is taken in segregating and transporting the desulfurized fuels, they will still have to be water washed to remove sodium, but the very low ash and vanadium contents will not only improve turbine availability by lengthening the operating cycle but they will also decrease operating costs by virtue of the decrease in additive costs required for corrosion inhibiting. This reduction may be as much as 70 to 80%.

Thus, with the advent of the availability of desulfurized fuel oils, the industrial gas turbine should find wider latitude in fuel selection and application. For instance, where applications of this type turbine for power plants or installations have previously been a matter of speculation, the use of the high quality desulfurized fuel now appears possible. The use of fuel oil would enable the use of low cost gas compressors which is important for economic factors.

Another application which should see wider use of the desulfurized fuels is in diesel engine installations. Bunker fuels are presently finding wide use in the larger low-speed diesels but the high sulfur, ash, and vanadium contribute towards higher operation and maintenance costs. The better quality available in the desulfurized fuel would, of course, be reflected in a general improvement in the operation of these engines.

FLUE GAS DESULFURIZATION

A potential alternative to burning low sulfur fuel to meet air quality standards will be to remove sulfur oxides from the flue gas before it is emitted from the stack. Flue gas desulfurization is expected to be applied primarily to power generation boilers, but it may be used in a few large industrial installations. There is essentially no prospect of its use in smaller installations.

Several processes are currently under development, and will probably be commercialized within the next few years. Among these, for example, are the alkalized alumina process being developed by the U.S. Bureau of Mines and the SO₂ oxidation process being developed by a group of companies headed by Monsanto. The alkalized alumina process removes SO₂ from the flue gas by adsorption on solid particles. It is then recovered by reduction to H₂S which is converted to free sulfur. The oxidation process converts SO₂ to SO₃ and recovers it as sulfuric acid. It is generally conceded that such processes will be economical only for large boilers. Even there, an important factor in the economics will be the by-product credits for recovery of sulfur either as sulfuric acid or as free sulfur. These credits will probably be greater than 10¢ per barrel of fuel oil burned, depending upon the amount of sulfur in the fuel. This will probably not be enough to pay the cost of desulfurization, but will help to offset it.

CONCLUSIONS

The general effect of air quality regulations which limit fuel oil sulfur content will be a trend toward better fuel oils which will give fewer operating problems. The changes which occur will be similar whether the fuels are made from natural low sulfur crude or by desulfurizing higher sulfur content components. The fuels will be lower in viscosity, which means easier handling and better atomization. They will be lower in ash content so superheater deposit and corrosion problems will be minimized. They will tend to make fewer stack solids. The problems caused by SO₂ cold end corrosion and acid smuts formation, will be eased, but good combustion control will still be required. They may have higher pour points, but simple changes to storage facilities will overcome any flow problems.

It is expected that these fuels will be somewhat more expensive than current fuels due to additional processing costs or the cost of transporting fuel to an area not normally tributary to the source. However, a substantial part of the increased fuel costs may be compensated for by decreased operating costs as a result of the improved fuel quality.

BIBLIOGRAPHY

1. Air Quality Criteria for Sulfur Oxides, U.S. Bureau of Health, Education, and Welfare, Public Health Service Publication 1970-100.
2. Heller, A., Nelson, Walters, D. L., "Impact of Oil Sulfur Content on Energy Use in Community Air Quality," Journal of the Air Pollution Control Assoc., 18, pp. 423-429, September 1967.
3. 1968 Book of ASTM Standards, Part 17, ASTM, January 1968.

REFERENCE QUALITY ASSESSMENT REPORT
(Source Category) Section 1.3

1. Reference Identification (using reference format described in Pedco Technical Procedures).
2. Is the reference data excluded from revision consideration, based on any of the following criteria? (Check the applicable response.)
See memo, 1969
no test series data
 - a. Test series averages reported in units that cannot be converted to the selected reporting units.
 - b. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front-half with EPA Method 5 front- and back-half).
 - c. Test series of controlled emissions for which the control device is not specified.
 - d. Test series in which the source process is not clearly identified and described.
 - e. Test series in which it is not clear whether the emissions measured were controlled or uncontrolled.
 - f. Test series emissions data is acceptable and will be assigned a quality rating.
3. The following evaluation applies to the quantity and quality of data reported.
 - a. Testing/Sampling Methodology (Circle the appropriate response)
 - Source operations - Documentation of the manner in which the source was operated is .
(good fair poor not applicable)
Comments: *NA*
 - Source operating parameters proceeded (as normal irregularly with only slight deviations) during the testing.
Comments: *NA*

- Documentation of sampling techniques and methods is (good fair poor) Comments: (please include analyzer instrumentation, reference gas, etc.)

NA

b. Data

- Data is questionable because of: (variations in testing parameters wide deviation of test results other) Comments:

NA

- Is VOC species data reported? (methane non-methane unspecified) Comments:

NA

- How is test data expressed? (original raw data sheets emission factors weight percent volume percent) Comments:

NA

c. Analysis and Calculations

- The nomenclature and equations used are comparable to those specified by EPA, to establish equivalency. (yes no identical) Comments:

—

- Is this reference data representative of the industry (source category) as a whole, or specific to only a segment of the industry? (entire industry segment) Comments:

—

- What is the approximate ratio of total number of facilities in the nation to the number of facilities tested? (i.e., total population vs. sample size)

Comments:

—

4. Additional comments:

old & outdated

(1962)

*Subject: future characteristics
of low-sulfur
fuel oils.*

5. This reference has been rated D .

(This rating scale is that outlined in the report entitled:
Technical Procedures for Developing AP-42 Emission Factors and
Preparing AP-42 Sections.)