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# DEVELOPMENT OF MOBILE DISSOLVED AIR FLOTATION AND FILTRATION (DAFF) PACKAGE PLANTS FOR EMERGENCY WATER SUPPLY OR POLLUTION CONTROL

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# DEVELOPMENT OF MOBILE DISSOLVED AIR FLOTATION AND FILTRATION (DAFF) PACKAGE PLANTS FOR EMERGENCY WATER SUPPLY OR POLLUTION CONTROL

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## ABSTRACT

Emergency, temporary, or seasonal water supply may be needed by a military hospital, a seriously flooded area, an industrial park, or a camp site. Similarly emergency remediation may be needed when water or land pollution accidentally occurred. Financial and personnel limitations faced by municipalities, farmers or industrial/commercial owners can be alleviated by adopting prefabricated mobile package water or wastewater treatment installations for lake water supply, lake-pond water restoration, groundwater decontamination, or site remediation. When an urgent water supply or pollution control is no longer needed, the mobile package installation may be moved to another location for similar services, or sold for the cost recovery. This publication introduces the high-rate mobile package plants developed by the Lenox Institute of Water Technology (LIWT), but built, marketed and installed by Krofta Engineering Corporation (KEC) and its associated companies around the world. Specifically two mobile DAFF package plants consisting of chemical coagulation/flocculation, dissolved air flotation (DAF), automatic backwash filtration and post chlorination are introduced. The first mobile DAFF plant (Sandfloat Type 8; Diameter = 8 ft.) incorporates all unit processes into one single unit, and has a design

capacity of 144,000 gpd. The second mobile DAFF plant (Sandfloat Type 4; Diameter = 4 ft) has identical unit process components, and has a design capacity of 14,400 gpd. Special emphasis is placed on introducing the mobile DAFF package plants' circular high rate dissolved air flotation (DT = 3 minutes), its zero-velocity concept, unique automatic filter backwash operation, design diagrams, physicochemical unit process sequence, stainless steel construction, mobility, and the feasibility of treating reservoir water, acidic lake water and industrial effluents. The mobile DAFF plants' various water supply applications and water pollution applications are reviewed. References are also cited for the applications of DAF/DAFF for groundwater decontamination, storm water treatment, industrial effluent pretreatment, and hydraulic fracturing wastewater treatment. This publication is one of the authors' short memoirs for partial documentation of the R&D and engineering accomplishments of LIWT and KEC.

[Key Words] Memoir, Lenox Institute of Water Technology, Krofta Engineering Corporation, Innovation, Water Purification, Water Pollution Control, Mobile Package Plants, Dissolved Air Flotation, Filtration, DAFF, DAF, Emergency Service, Seasonal Operation, Small Water System, Reservoir, Lake, Acid Rain, Groundwater Decontamination, Site Remediation.

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## ACRONYM

| | |
|---|---|
| AWWA | American Water Works Association |
| DAF | Dissolved air flotation |
| DAFF | Dissolved air flotation and filtration |
| DEQE | Department of Environmental Quality Engineering |
| gpd | Gallons per day |
| gpm | Gallons per minute |
| KEC | Krofta Engineering Corporation |
| LIWT | Lenox Institute of Water Technology |
| MGD | Million gallons per day |
| NYSDH | New York State Department of Health |
| R&D | Research and development |
| STEAM | Science, technology, engineering, arts and mathematics |
| USEPA | U.S. Environmental Protection Agency |

# 1. INTRODUCTION

## 1.1 Dissolved Air Flotation and Filtration (DAFF) Mobile Package Plants

There is a constant need of (a) having emergency, temporary, or seasonal water and wastewater treatment facilities and services when facing natural disasters, military operations, large flea markets, hazardous waste spills, popular music fairs, site remediation projects, etc. ; and (b) providing affordable water and wastewater treatment facilities to small communities in rural areas, agricultural farming facilities, year-round camping or training facilities, etc. [1-20]. To meet the above demands, treatment efficiency, affordability, mobility, and reusability are the four most important factors for the process equipment selection and design. First of all the selected process equipment must be able to perform. Traditionally a physicochemical treatment system consisting of chemical coagulation/flocculation, clarification, filtration (including membrane filtration), and disinfection is used for potable water treatment, but a biological process system, such as activated sludge, trickling filter, rotating biological contactors, sequencing batch bioreactors, membrane bioreactors, etc. is normally used for wastewater treatment due to the fact that the treatment cost of a biological process system is lower than that of a conventional physicochemical treatment process system. [ 21-69] It has been proven that an independent physicochemical process system can also technically and cost-effectively treat wastewater if a dissolved air flotation (DAF), such as Supracell clarifier, with only about 3 minutes of detention time (DT) is used for clarification. [61]. Adoption of a high rate DAF clarification (DT = 3 minutes) instead of a conventional sedimentation clarification (DT = 60 minutes) significantly (a) reduces the process equipment size, (b) improves the process reactor structure (using stainless steel structure instead of concrete structure); (c) reduces process equipment costs due to much smaller equipment size; (d) increases mobility when the small DAF process equipment is on wheels; and (e) increases the reusability due to DAF's stainless steel structure and mobility. All the above high-rate DAF advantages are achievable due to adoption of its unique "Zero-Velocity Design" explained by Wang et. al. [63]. A combination of a circular high rate DAF clarifier and a circular automatic backwash filer becomes a package treatment plant, known as Sandfloat or DAFF, which inherits all the above advantages of Supracell (DAF). [60, 62]. This publication introduces the high-rate dissolved air flotation and filtration (DAFF) package plants for small communities and industries, and the DAFF mobile package plants for emergency, seasonal or temporary applications. All these DAFF plants were developed by the Lenox Institute of Water Technology (LIWT), and built and installed by Krofta Engineering Corporation (KEC) and its associated companies around the world.

LIWT & KEC have designed and installed the first potable flotation plant (Sandfloat DAFF Type 22; 1.2 MGD capacity) in the U.S. [1-13]. This small DAFF water treatment unit with a diameter of 22 ft. is able to process 1.2 MGD potable water serving 6000 people in Lenox, Massachusetts, USA. This publication also introduces two scaled-down mobile potable water flotation plants for small communities. Both consist of chemical mixing, flocculation, dissolved air flotation, sand filtration (DAFF) and post chlorination. The first mobile DAFF plant (Sandfloat Type 8; Diameter = 8 ft.) incorporates all unit processes into one single unit, and has a design capacity of 144,000 gpd. The second mobile DAFF plant (Sandfloat Type 4; Diameter = 4 ft) has identical unit process components, and has a design capacity of 14,400 gpd. The mobile plants' feasibilities of treating reservoir water, acidic lake water are demonstrated. The mobile plants' results for groundwater decontamination are reviewed. The authors write this short memoir for partial documentation of the engineering accomplishments of LIWT and KEC.

## 1.2 Emergency, Temporary or Seasonal Applications of Mobile Package Treatment Plants for Pollution Control

Emergency, seasonal, or temporary water pollution control may occasionally be needed in a military hospital, a seriously flooded area, an industrial park, a large music event, or a religious gathering, etc. Emergency/temporary water pollution control may also be needed when hazardous substances spill, or leachate leakage from a landfill site accidentally occurred. Financial and personnel limitations faced by municipalities or industrial owners can be alleviated by prefabricated mobile package wastewater treatment installations for leachate treatment, lake water restoration, groundwater decontamination, or site remediation. When an urgent water pollution control project is completed and no longer needed, the mobile package installation may be moved to another location for similar services, or be sold for the cost recovery.

A mobile water or wastewater treatment package plant, such as Sandfloat DAFF, or equivalent, can be tailored for treating various source waters ranging from natural, industrial, agricultural, municipal, commercial, or accidental sources, such as storm water [23, 70], surface impoundments [5-20], industrial effluents [30, 31, 37, 41, 42, 45, 46-55, 70], agricultural lagoons and ponds [70], municipal gray water [24, 25, 30, 31, 43, 54, 59, 60, 62], municipal landfill leachate [68], cooling tower blowdown [34, 35, 40], contaminated lake water [18-20, 32, 43, 60], golf course irrigation water [70], contaminated groundwater [70, 71], hydraulic fracturing wastewater [72], etc.

## 1.3 Emergency, Temporary or Seasonal Applications of Mobile Package Treatment Plants for Water Supply.

Water supply systems in rural areas share, in principle, the general features of large urban water supply systems. However, rural water supply systems have to fit the needs of the rural populations served. The rural populations are usually small in density, and scattered over wide areas. Often it is economically unfeasible to install long water transmission lines for water treatment in a regional water purification plant.

The source of the rural water supply will usually be underground aquifers rather than river or lake waters. In comparison with urban water supply systems, the pumping, distribution, storage, and treatment facilities of rural water supply systems are smaller, simpler, and less costly because ground water usually is cleaner than surface water.

Existing water treatment technologies, such as flocculation/sedimentation/filtration, ion exchange, granular carbon adsorption, etc., are often too costly or operationally complex for installation in single family homes or in small community water systems serving less than 3300 persons. It is reported by American Water Works Association Research Foundation [1] that these small water supply systems comprise approximately 78 percent of the number of water supplies in this country. Most small water systems use only chlorination for water disinfection, thus are not considered to be adequate [2].

LIWT and KEC have developed two small package water treatment plants, (Sandfloats) far specific applications on individual homes and small water supply systems. This research was aimed at evaluating the Sandfloat DAFF package plant which has extremely low detention time, high treatment efficiency, and low costs thus becoming a potential cost-effective solution to the common problems affecting the drinking water quality of a rural single family home or a typical small community, and is within the technical expertise of small system operations.

The Drinking Water Research Division of the U.S. Environmental Protection Agency (USEPA) has funded, and is funding, several research projects in this study area of small system technology. The current USEPA studies include: cost evaluation; arsenic removal by reverse osmosis, ion exchange and activated alumina; uranium removal; reverse osmosis evaluation; fluoride and selenium removal by activated alumina and ion exchange; nitrate removal by ion exchange; barium and radium reduction by ion exchange; disinfection alternatives; and turbidity removal by various filtration methods (slow sand, direct, diatomaceous earth) Partial USEPA study was documented elsewhere [3] . This research project, completed in response to the American Water Works

Association (AWWA) Research Foundation research project announcement (3/28/84) "Small System Technology", does not duplicate the previous or on-going work conducted by USEPA or others.

The first potable water DAFF plant (Sandfloat Type 22; 1.2 MGD capacity) has been successfully serving 6000 people in Lenox, MA, USA, since 1982 [4-13, 24, 43, 57, 60]. Another Sandfloat DAFF plant with 2 MGD has been serving the Town of Lee, MA, USA since 1998.[66]. There are many other Sandfloat DAFF plants serving small communities and industries for domestic and industrial water supply around the world. [24, 60, 70]

This publication introduces two scaled-down potable flotation plants for small communities. Both consist of flocculation, dissolved air flotation, sand filtration, and post chlorination. The first DAFF plant (Sandfloat Type 8) incorporates all unit processes into one single unit, and has a design capacity of 144,000 gpd. The second Sandfloat DAFF system has individual unit process components, and has a design capacity of 14,400 gpd. Their feasibilities of treating reservoir water and acid rain contaminated lake water are demonstrated.

## 2. DEVELOPMENT OF HIGH-RATE DISSOLVED AIR FLOTATION AND FILTRATION (DAFF) MOBILE PACKAGE PLANT (SANDFLOAT TYPE 8; 0.144 MGD)

The Krofta Sandfloat Type 8 consists of flocculation, dissolved air flotation and sand filtration processes, and is commercially available from Krofta Engineering Corporation or its associated companies around the world. It was scaled-down by the engineering firm specifically for small communities, or organizations.

The scaled-down Sandfloat Type 8 has a design capacity of 100 gpm, or 144,000 gallons per day. Assuming the water consumption rate in rural areas is 100 gallons per capita per day, one small Sandfloat Type 8 package plant can serve about 1,440 people.
The top view, side view and description of Sandfloat Type 8 are given in Figures 1A and 1B. A mobile Sandfloat DAFF is a phycicochemical process system consisting of the following process steps: (a) Step 1: chemical coagulation/flocculation, shown in Figure 2A; (b) Step 2: dissolved air flotation clarification shown in Figure 2A; (c) Step 3: filtration and automatic backwash operations, shown in Figure 2B; and (d) Step 4: floated sludge removal, shown in Figure 2B.

Figure 3A shows the top view and side view of a mobile Sandfloat daff type 8 package plant; while Figure 3B presents the Sandfloat DAFF Type 8 equipment list and flow list that corresponds to the same Sandfloat equipment graphically illustrated in Figure 3A.

Figure 4 is a picture of mobile Sandfloat DAFF Type 8 package plant. Figure 5 is photo showing the same mobile Sandfloat DAFF Type 8 package plant is on wheels.

All Figures 1-5 together graphically demonstrate that this small innovative package plant system can be easily mounted on a trailer to increase its mobility for water supply to more than one small community or for its possible service in a remote camping site, construction site, battle field, etc. It has been further experimentally demonstrated that the Sandfloat Type 8 is feasible for significant removal of turbidity, color, trihalomethane precursors (in terms of trihalomethane formation potential, UV absorbance, humic substances etc.), coliform bacteria, from the raw water of the City of Rome, New York, USA. The operation of Sandfloat Type 8 package plant in Rome was monitored by the New York State Department of Health (NYSDH) in November 1983 to March 1984. Table 1 presents the summary of typical monthly performance data. [14-17]

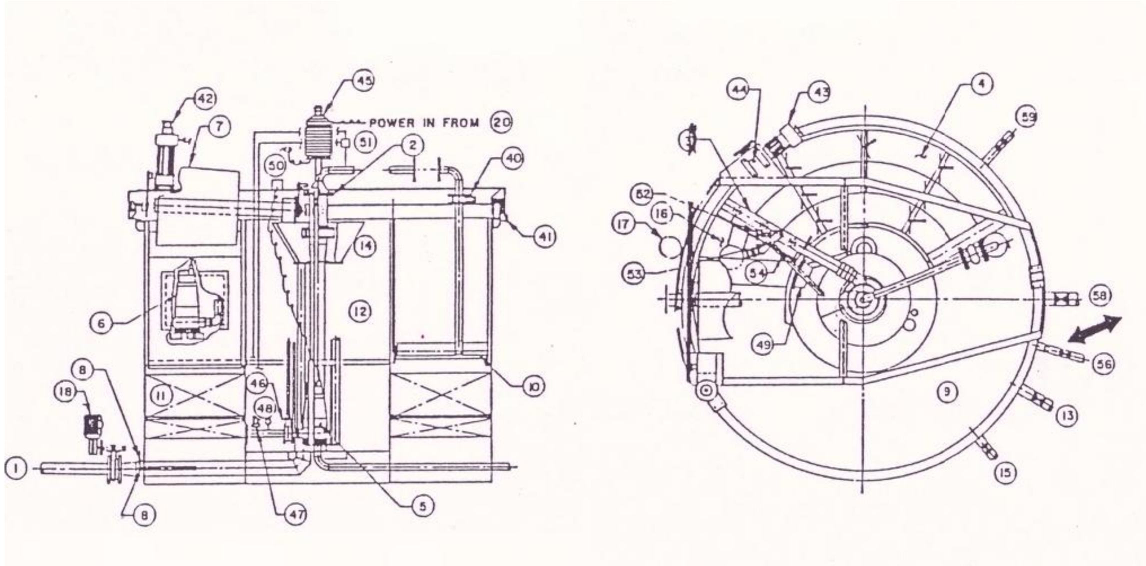


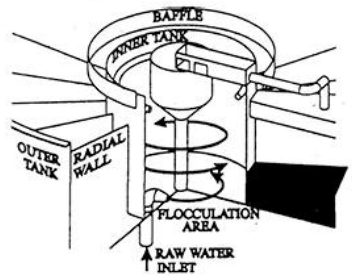

Figure 1A.  Top View, Side View and Description of Krofta Sandfloat DAFF Type 8

1. RAW WATER INLET
2. HYDRAULIC ROTARY JOINT
3. RAPID MIXING SECTION
4. FLOCCULATOR
5. BACKWASH WASHING PUMP
6. BACKWASH RECYCLE PUMP
7. SLUDGE DISCHARGE SCOOP
8. CHEMICAL LINES
9. FLOTATION TANK
10. PRESSURE RELEASE MANIFOLD
11. SAND FILTER (SILICA SAND 11" DEPTH)
12. CLEAR WELL
13. CLEAR WELL EFFLUENT OUTLET (GATE VALVE)
14. CENTER SLUDGE COLLECTOR
15. FLOATED SLUDGE OUTLET (GATE VALVE)
16. BACKWASH HOOD AREA
17. LEVEL CONTROL
18. INLET MOTORIZED BUTTERFLY VALVE
19. CLEAR WELL ELECTRODES
20. CONTROL PANEL
21. RAW WATER INLET MANUAL VALVE
22. INELT FLOW METER
23. CHEMICAL PUMP DISCHARGE GATE VALVE
24. CHEMICAL PUMP
25. PRESSURE PUMP SUCTION GATE VALVE
26. PRESSURE PUMP DISCHARGE GATE VALVE
27. PRESSURE PUMP
28. Δ PRESSURE GATE VALVE
29. PRESSURE GAUGE 0-100 PSI
30. Δ PRESSURE GATE VALVE
31. SAFETY VALVE SET TO 100 PSI
32. AIR DISSOLVING TUBE
33. AIR DISSOLVING TUBE INLET ORIFICE
34. AIR COMPRESSOR 55 SCFH @ 90 PSI
35. AIR FILTER
36. AIR REGULATOR
37. AIR ROTOMETER 0 - 50 SCFH @ STD
38. GATE VALVE
39. GATE VALVE
40. PRESSURE REDUCING BUTTERFLY VALVE
41. LIMIT SWITCH
42. SCOOP DRIVE MOTOR
43. CARRIAGE DRIVE MOTOR
44. CARRIAGE DRIVE WHEEL
45. ELECTRICAL ROTARY CONTACT
46. BUTTERFLY VALVE
47. BACKWASH CYLINDER
48. PRESSURE GAUGE (0-100 PSI)
49. BACKWASH SHOE
50. DELAY TIMER
51. SOLENOID VALVE
52. GATE VALVE
53. PRESSURE GAUGE (0-100 PSI)
54. GATE VALVE
55. CLEAR WELL SITE TUBE
56. CLEAR WELL DRAIN (GATE VALVE)
57. BLEED OFF VENT
58. PRESSUREIZED INLET (GATE VALVE)
59. PRESSURIZED SUCTION PIPE (GATE VALVE)

Figure 1B. Sandfloat DAFF Process Equipment Description Numbers in Figure 1B Corresponding to the Description Numbers in Figure 1A

### Flocculation

Raw water mixed with flocculating agents enters through a system of nozzles into the flocculating chamber of the unit. The resulting gentle mixing velocity causes solids to aggregate together forming flocs. The extended floc tank assures proper flocculation detention time.




### Flotation/Clarification

Water with flocculated solids flows out of the flocculation tank, passing over an area where air saturated water is released. An air dissolving tube system located outside the SANDFLOAT unit generates microscopic, entrained air bubbles which attach themselves to the floc particles, causing them to float to the surface. Laminar plates located under the main flotation zone allow hydraulic loading to 4-5 GPM/SF. (1 GPM/SF = 40 LPM/M²)

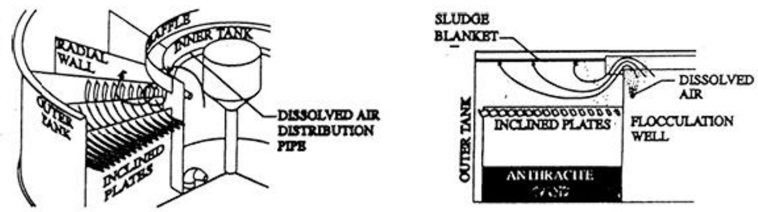
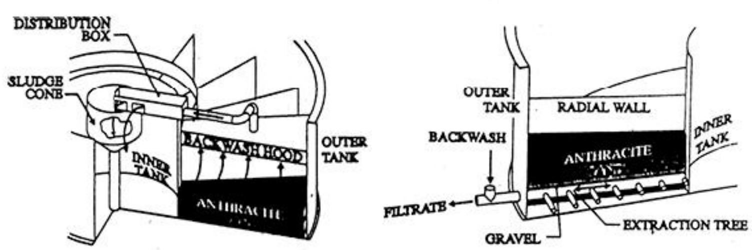



Figure 2A. Sandfloat DAFF Physicochemical Process Descriptions for Step 1 (Chemical Coagulation/Flocculation ) and Step 2 (Dissolved Air Flotation Clarification)

### Filtration/ On-Line Backwashing

One dual media sandfilter section is individually backwashed while the other sections continue to filter water. Water from the first filtrate water reservoir is pumped from below, through the filter media, washing out impurities. Backwash water is recycled back to the flocculation chamber. The first filtrate (after backwash) isolation system allows for meeting potable water design standards.




### Sludge Removal

The rotating KROFTA *Spiral Scoop* mounted on the carriage, circulates around the unit, gently lifting the floated impurities from the water surface. The sludge, at 1-3% consistency, is emptied into the central collector for removal from the SANDFLOAT unit.

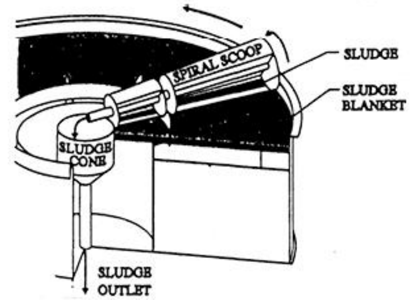



Figure 2B. Sandfloat DAFF Physicochemical Process Descriptions for Step 3 (Filtration and Automatic Backwash Operations) and Step 4 (Floated Sludge Removal)

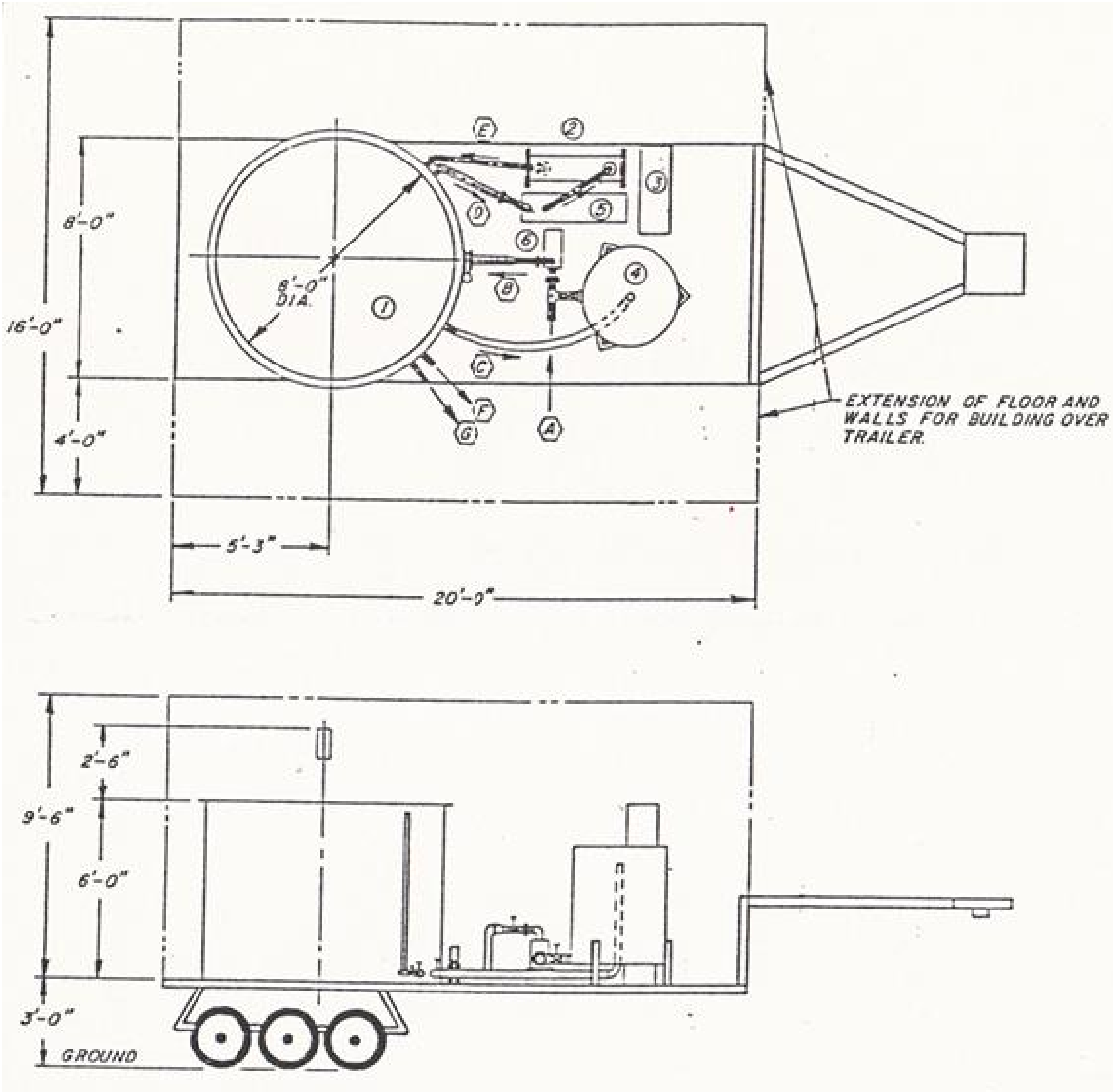



Figure 3A. Top View and Side View of Mobile Sandfloat DAFF Type 8 Package Plant

EQUIPMENT LIST

1-KROFTA SANDFLOAT 8'-160,000 GPD
2-KROFTA AIR DISSOLVING TUBE TYPE 300
3-CONTROL PANEL - POWER 208V/3PH
4-HOLDING TANK-260 GAL. (NOTE: ONLY USED IF RECYCLE FLOW IS REQUIRED.)
5-ADT PRESSURE PUMP- 30 GPM @ 200 ft HD
6-FEED PUMP-148 GPM @ 20ft HD

FLOW LIST

A-RAW WATER INLET FROM CUST. PIPE
B-RAW WATER INLET FROM PUMP (6)
C-CLEAN WATER TO TANK (4) OR CUST. TANK
D-WATER FEED TO ADT PRESSURE PUMP (5)
E-AERATED WATER TO SAF (1)
F-SLUDGE OUTLET
G-DRAIN

Figure 3B. Sandfloat DAFF Type 8 Equipment List and Flow List Corresponding to the Same Sandfloat Equipment Graphically Illustrated in Figure 3A


Figure 4.  A Picture of Mobile Sandfloat DAFF Type 8 Package Plant


Figure 5. Mobile Sandfloat DAFF Type 8 Package Plant on Wheels

TABLE 1. TYPICAL MONTHLY PERFORMANCE DATA OF SANDFLOAT TYPE 8 IN ROME, NEW YORK, USA (11/07/83 - 12/09/83)

| PARAMETERS | RANGE | AVERAGE | U.S. DRINKING WATER STANDARDS |
|---|---|---|---|
| **INFLUENT** | | | |
| Flow, gpm | 100 | 100 | |
| Temperature, $^{o}F$ | 34-40 | 37.6 | |
| pH, unit | 7.1-7.3 | 7.2 | |
| Turbidity, NTU | 0.65-1.2 | 0.89 | |
| Color, unit | 40-50 | 42.5 | |
| Microscopic Count, #/ml | 4214-12939 | 8833 | |
| Aluminum, ppm | 0-0.074 | 0.013 | |
| Alkalinity, ppm $CaCO_3$ | 10-21 | 15.4 | |
| THMFP, ppb | 127-493 | 303 | |
| UV (254 nm) | .169-.213 | 0.185 | |
| Total Coliform, #/100 ml | <1-TNTC | | |
| Total Plate Count #/1 ml | 4-6 | 5.0 | |
| Humic Substances, ppm | 4.2-6.0 | 5.6 | |
| Polymer, Type | 1849A | 1849A | |
| Polymer Dosage, ppm | 1.5-2.0 | 1.9 | |
| Sodium Aluminate, ppm | 4.8-6.4 | 6.1 | |
| Alum, ppm $Al_2(SO_4)_3 \cdot 14\ h_2O$ | 17.4-29.6 | 23.1 | |
| Other Chemical, Type | NONE | NONE | |
| Other Chemical, ppm | 0 | 0 | |
| **SANDFLOAT EFFLUENT, UNCHLORINATED** | | | |
| Flow, gpm | 98.5-99.4 | 98.9 | |
| pH, unit | 6.8-7.1 | 7.0 | |
| Turbidity, NTU | 0.1-0.39 | 0.12 | |
| Color, Unit | 2 | 2.0 | |
| Microscopic Count, #/ml | 13-67 | 37 | |
| Aluminum, ppm | 0-.014 | 0.005 | |
| Alkalinity, ppm $CaCO_3$ | 7-16 | 9.0 | |
| THMFP, ppb | 19-97 | 61.2 | <100 |
| Chlorine Demand, ppm | .65-1.5 | 1.2 | |
| UV (254 nm) | .019-.045 | 0.034 | |
| Total Coliform, #/100 ml | <1 | <1 | |
| Total Plate Count #/1 ml | 0 | 0 | |
| Humic Substances, ppm | 0.3-3.1 | 1.19 | |
| **CHLORINATED EFFLUENT** | | | |
| pH, unit | 6.9-7.7 | 7.2 | 6.5-8.5 |
| Turbidity, NTU | 0.2-0.3 | .2 | < 1 |
| Color, unit | 0-3 | 1.0 | <15 |
| Microscopic Count, #/ml | NA | NA | |
| Aluminum Residue, ppm Al | 0-0.014 | 0.005 | |
| Chlorine Residue, ppm | .2-.45 | .3 | |
| Temperature, $^{o}F$ | 34-40 | 37.6 | |
| Corrosion Control | OK | OK | non corrosive |
| THMFP, ppb | 19-97 | 61.2 | <100 |
| Total Coliform, #/100 ml | 0 | 0 | 0 |
| Total Plate Count | 0 | 0 | |
| **SLUDGE FROM SANDFLOAT** | | | |
| Flow, gpm | .6-1.5 | 1 | |
| Total Suspended Solids, ppm | 394-4213 | 2433 | |

## 3. DEVELOPMENT OF HIGH-RATE DISSOLVED AIR FLOTATION AND FILTRATION (DAFF) MOBILE PACKAGE PLANT (SANDFLOAT TYPE 3; 0.0144 MGD)

LIWT and KEC together have also developed a miniature Sandfloat treatment system consisting of the following individual treatment components: a mixing tank, a static hydraulic flocculation tank, a dissolved air flotation tank (Supracell Type 3; Diameter = 3 ft.), and three sand filters.

The system has a design capacity of 10 gpm, or 14,400 gallons per day, or 0.0144 MGD. This compact system can serve 144 people in a small housing development, or a town house complex. It too can be mounted on a trailer to have maximum mobility. Under the supervision of the City of Pittsfield and the Commonwealth of Massachusetts, Department of Environmental Quality Engineering (DEQE) in Boston, MA, USA, raw water from Ashley and Farnham Reservoirs in Berkshire County, Massachusetts, was successfully treated by this miniature Sandfloat system in October-December 1983. Table 2 summarizes the performance data. [18-20]. It is clear that turbidity, color, trihalomethane formation potential, coliform bacteria, iron, manganese, lead and giardia cyst-sized particles (in terms of microscopic particle count) were significantly removed from the City of Pittsfield's raw water supply. The process system easily met all the U.S. Environmental Protection Agency and the Massachusetts Drinking Water Standards.

In July 1984, the miniature Sandfloat DAFF system was used to treat the acid-rain contaminated South Pond water. South Pond is located in northwestern Massachusetts, USA, about 6 miles southeast of North Adams, Massachusetts and the same distance south of the Vermont border. The pond lies at an elevation of 1980 feet in the Berkshire Hills, and has an area of 18 acres. It is a shallow lake with an average depth of 10 feet having very limited and low-growing aquatic vegetation along the bottom. Predominant fish species include bullhead and panfish in low numbers. Surrounding the lake is a mixed northern hardwood forest of hemlock, beech, and sugar maple trees, with a blend of mountain laurel and blueberry bushes along the shoreline. During the summer months the eastern 150 feet of shoreline is used as a campground beach for Savoy State Forest's 45 site area. South Pond has no cabins, cottages, or other facilities dumping wastewater along it's shore, and the State of Massachusetts also prohibits fishermen and boaters from using gas powered motors on the pond. However, the South Pond water has been contaminated by acid rain. Table 3 presents the raw water quality and treatment results. From the table, it can be seen that the raw water quality was poor in terms of extremely low pH, high acidity, color, turbidity, sulfate and coliform bacteria. Since the raw water sulfate content was high and its nitrate content was low, we can reasonably conclude that the lake water was acidified by sulfur dioxide, not by nitrogen oxides. It is encouraging to see (from Table 3) that flotation treatment (using sodium aluminate and lime) in the first stage, the South Pond water is suitable for recreational purposes. After the second stage filtration treatment, the filter effluent became potable and is suitable for domestic consumption. The final effluent was neutral in pH, low in color, turbidity, acidity, nitrate and sulfate, and zero in phosphate and coliforms. The readers are referred to Shammas and Wang [73, 74] for the water quality criteria, theory, principles, design criteria, design examples, and glossary terms concerning chemical feeding, mixing, flocculation, dissolved air flotation, sand filtration, granular activated carbon (GAC) adsorption, disinfection, corrosion control, etc. which are all related to the domestic and industrial water supply using DAFF. In a DAFF system, either sand filtration (or multi-media filtration), or GAC can be used. For proper water treatment, disinfection and corrosion control are required, but not discussed in this publication.

TABLE 2. PERFORMANCE DATA OF MINIATURE SANDFLOAT SYSTEM FOR TREATMENT OF RAW WATER FROM ASHLEY AND FARNHAM RESERVOIRS (11/12/83-12/12/83)

| PARAMETERS | RANGE | U.S. DRINKING WATER STANDARDS |
|---|---|---|
| **INFLUENT** | | |
| Flow, gpm | 3.2-12 | |
| Temperature, $^{o}F$ | 39.2-62.6 | |
| pH, unit | 6.1-7.5 | |
| Turbidity, NTU | 1-3.5 | |
| Color, unit | 25-70 | |
| Microscopic Count, #/ml | 1967-17328 | |
| Aluminum, ppm | 0-0.17 | |
| Alkalinity, ppm $CaCO_3$ | 4-39 | |
| THMFP, ppb | 73-577 | |
| UV (254 nm) | 0.056-0.303 | |
| Total Coliform, #/100 ml | NA | |
| Iron, ppm | 0.03-0.78 | |
| Manganese, ppm | 0-0.15 | |
| Chlorine Demand, ppm | 0.7-3.3 | |
| Polymer, Type | 1849A | |
| Polymer Dosage, ppm | 0.5-1 | |
| Sodium Aluminate, ppm $Al_2O_3$ | 6-13 | |
| Alum Dosage, ppm $Al_2O_3$ | 5-6 | |
| Other Chemical, Type | LIME | |
| Other Chemical Dosage, ppm | 0-13.5 | |
| **FILTER EFFLUENT, UNCHLORINATED** | | |
| Flow, gpm | 7.38-11.9 | |
| pH, unit | 6.8-8 | 6.5-8.5 |
| Turbidity, NTU | 0.1-0.7 | < 1 |
| Color, Unit | 0-5 | < 15 |
| Microscopic Count, #/ml | 5-125 | |
| Aluminum, ppm Al | 0-0.1 | |
| Alkalinity, ppm $CaCO_3$ | 4-31 | |
| THMFP, ppb | 4-18 | <100 |
| Chlorine Demand, ppm | 0.4-1.5 | |
| UV (254 nm; 1 cm light path | 0.027-0.097 | |
| Total Coliform, #/100 ml | 0-2 | 1 |
| Iron, ppm | 0-0.08 | 0.3 |
| Manganese, ppm | 0-0.09 | 0.05 |
| **CHLORINATED WATER** | | |
| Chlorine Type | $Cl_2$ or $Ca(OCl)_2$ | |
| Chlorine Dosage, ppm $Cl_2$ | 0.62-1.71 | |
| Corrosion Control Chemical | SSN or SMP | |
| Corrosion Control Chemical, ppm | 7-20 | |
| pH, unit | 7.1-8 | 6.5-8.5 |
| Turbidity, NTU | 0.2-0.4 | < 1 |
| Color, unit | 0-5 | <15 |
| Aluminum Residue, ppm Al | 0-0.1 | |
| Chlorine Residue, ppm | 0.1-0.4 | |
| Total Coliform, #/100 ml | 0 | 0 |
| **SLUDGE FROM PILOT PLANT** | | |
| Flow, gpm | 0.08-0.15 | |
| Total Suspended Solids, ppm | 1148-2693 | (Between Backwash) |
| | 1145-3390 | (During Backwash) |

TABLE 3

TREATMENT OF ACIDIC LAKE WATER
CONTAMINATED BY ACID RAIN

| PARAMETERS | RAW LAKE WATER (BEFORE) | FLOTATION EFFLUENT (1ST STAGE) | FILTRATION EFFLUENT (2ND STAGE) |
|---|---|---|---|
| pH, unit | 4.9 | 7.0 | 7.1 |
| Color, unit | 3.5 | 0.3 | 0.1 |
| Turbibity, NTU | 2.8 | 0.8 | 0.5 |
| Acidity mg/L $CaCO_3$ | 24.0 | 1.9 | 1.8 |
| $NO_3$-N, mg/l | 0.4 | 0.3 | 0.2 |
| $PO_4$-P, mg/l | 0.1 | 0 | 0 |
| $SO_4$, mg/l | 70.0 | 10.0 | 9.0 |
| Coliforms, #/100 ml | 160 | 1 | 0 |

Notes:

a. Krofta miniature Sandfloat system consisting of a mixing chamber, a flocculation chamber, a dissolved air flotation clarifier, and three sand filters, was used for treatment.

b. Sampling and testing date: July 26, 1984.

c. Chemical treatment was 4.4 mg/l of Sodium aluminate as $Al_2O_3$ and 3.5 mg/l of calcium hydroxide

d. Lake water was sampled from South Pond, Florida, Massachusetts, USA

e. Chemist and Operator: Mrs. Betty C. Wu and Mr. Robert A. Foote of the Lenox Institute

GLOSSARY

**Dissolved air flotation (DAF):** One of dissolved gas flotation (DGF) processes when air is used for generation of gas bubbles. A typical example is Krofta Engineering Corporation's Supracell clarifier; See dissolved gas flotation (DGF).

**Dissolved air flotation-filtration (DAFF**): A package plant which consists of both dissolved air flotation and filtration. A typical example is Krofta Engineering Corporation's Sandfloat clarifier.

**Dissolved gas flotation (DGF):** It is a process involving pressurization of gas at 25 to 95 psig for dissolving gas into water, and subsequent release of pressure (to one atm) under laminar flow hydraulic conditions for generating extremely fine gas bubbles (20-80 microns) which become attached to the impurities to be removed and rise to the water surface together. The impurities or pollutants to be removed are on the water surface are called float or scum which scooped off by sludge collection means. The clarified water is discharged from the flotation clarifier's bottom. The gas flow rate is about one percent of influent liquid flow rate. The attachment of gas bubbles to the impurities can be a result of physical entrapment, electrochemical attraction, surface adsorption, and/or gas stripping. The specific gravity of the bubble-impurity agglomerate is less than one, resulting in buoyancy or non-selective flotation (i.e. Save-All).

**Krofta Engineering Corporation (KEC):** It is an equipment manufacturer and engineering design company in Lenox, Massachusetts, USA, working closely with the Lenox Institute of Water Technology (LIWT) for develop, production, sales, installation and operation of innovative water and wastewater treatment processes, monitoring devices and analytical methods.

**Lenox Institute of Water Technology (LIWT):** It is a non-profit college in Massachusetts, USA, with expertise in environmental STEAM (science, technology, engineering, arts and mathematics) education, R&D, invention, process development, monitoring system/methods development, patent application, licensing, fund raising, engineering design and project management. LIWT teams up with Krofta Engineering Corporation (KEC), for technology transfer, equipment design, and voluntary humanitarian global service through free education, training, and academic publications.

**Sandfloat:** It is the combination of a circular high-rate dissolved air flotation clarifier and a circular automatic backwash granular filtration (DAFF) developed by the Lenox Institute of Water Technology (LIWT), and manufactured by Krofta Engineering Corporation (KEC) and its associated companies. The granular filtration can be sand filtration and/or granular activated carbon (GAC) filtration.

**Supracell:** It is a circular high-rate dissolved air flotation (DAF) clarifier developed by the Lenox Institute of Water Technology (LIWT), and manufactured by Krofta Engineering Corporation (KEC) and its associated companies.

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# APPENDIX A

Editors of

"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"

## 1. Dr. Lawrence K. Wang (王抗曝)

Editor Lawrence K. Wang has served the society as a professor, inventor, chief engineer, chief editor and public servant (UN, USEPA, NY, Albany) for 30+ years, with experience in entire field of environmental science, technology, engineering, arts and mathematics (STEAM). He is a licensed NY-MA-NJ-PA-OH Professional Engineer, a certified NY-MA-RI Laboratory Director, a MA-NY Water Operator, and an OSHA Train-the-Trainer Instructor.

He has special passion, and expertise in developing various innovative technologies, educational programs, licensing courses, international projects, academic publications, and humanitarian organizations, all for his dream goal of promoting world peace. He is a retired Acting President/Professor of the Lenox Institute of Water Technology (LIWT), USA, a United Nations Industrial Development Organization (UNIDO) Senior Advisor in Vienna, Austria, and a former professor/visiting professor of Rensselaer Polytechnic Institute, Stevens Institute of Technology, University of Illinois, National Cheng Kung University, Zhejiang University, and Tongji University.

Dr. Wang is the author of 750+ papers and 50+ books, and is credited with 29 invention patents. He holds a BSCE degree from National Cheng Kung University, Taiwan, ROC, a MSCE degree from the University of Missouri, a MS degree from the University of Rhode Island and a PhD degree from Rutgers University, USA. Currently he is the book series editor of CRC Press, Springer Nature Switzerland, Lenox Institute Press, World Scientific Singapore, and John Wiley.

Dr. Wang has been a Delegate of the People to People International Foundation, an American Academy of Environmental Engineers (AAEE) Diplomate, a member of WEF, AWWA, ASCE, AIChE, ASPE, CIE and OCEESA, and a recipient of WEF Kenneth Research Award (NY), Five-Star Innovative Engineering Award (first DAF drinking water plant in Americas), and Korean Pollution Control Association Award (Transfer of flotation technology to South Korea).

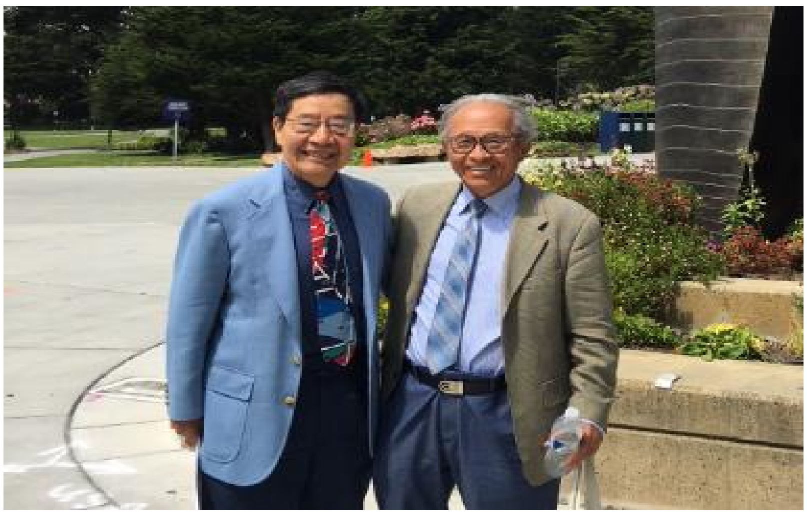
**2. Dr. Hung-ping Tsao (曹 恆 平)**

Editor Hung-ping Tsao has been a mathematician, a university professor, and an assistant actuary, serving private firms and universities in the United States and Taiwan for 30+ years. Dr. Tsao has been an Associate Member of the Society of Actuaries and a Member of the American Mathematical Society.

His research have been in the areas of college mathematics, actuarial mathematics, management mathematics, classic number theory and Sudoku puzzle solving. In particular, bikini and open top problems are presented to share some intuitive insights and some type of optimization problems can be solved more efficiently and categorically by using the idea of the boundary being the marginal change of a well-rounded region with respect to its inradius; theory of interest, life contingency functions and pension funding are presented in more simplified and generalized fashions; the new way of the simplex method using cross-multiplication substantially simplified the process of finding the solutions of optimization problems; the generalization of triangular arrays of numbers from the natural sequence based to arithmetically progressive sequences based opens up the dimension of explorations; the introduction of an innovative way to solve Sudoku puzzles makes everybody's life so much easier and other STEAM project development.

Dr. Tsao is the author of 10+ books and over 40 academic publications. Among all of the above accomplishments, he is most proud of solving manually in the total of ten hours the hardest Sudoku posted online by Arto Inkala in early July of 2012 and introducing an easy way to play Sudoku in 2019.

He earned his high school diploma from the High School of National Taiwan Normal University, his BS and MS degrees from National Taiwan Normal University, Taipei, Taiwan, his second MS degree from the UWM in USA, and a PhD degree from the University of Illinois, USA.



Editors of the eBOOK Series of the *"EVOLUTIONARY PROGRESS IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"*

Dr. Lawrence K. Wang (王抗曝) - - left

Dr. Hung-ping Tsao (曹恆平) -- right

# APPENDIX B

## THE E-BOOK SERIES OF

## *"EVOLUTIONARY PROGRESS IN SCIENCE,TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM)"*

The acronym STEM stands for “science, technology, engineering and mathematics”. In accordance with the National Science Teachers Association (NSTA), “A common definition of STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy”.

The problem of this country has been pointed out by the US Department of Education that “All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers.” STEM learning and applications are very popular topics at present, and STEM related careers are in great demand.

According to the US Department of Education reports that the number of STEM jobs in the United States will grow by 14% from 2010 to 2020, which is much faster than the national average of 5-8 % across all job sectors. Computer programming and IT jobs top the list of the hardest to fill jobs.

Despite this, the most popular college majors are business, law, etc., not STEM related. For this reason, the US government has just extended a provision allowing foreign students that are earning degrees in STEM fields a seven month visa extension, now allowing them to stay for up to three years of “on the job training”. So, at present STEM is a legal term.

The acronym STEAM stands for “science, technology, engineering, arts and mathematics”. As one can see, STEAM (adds “arts”) is simply a variation of STEM. The word of “arts” means application, creation, ingenuity, and integration, for enhancing STEM inside, or exploring of STEM outside.

It may also mean that the word of “arts” connects all of the humanities through an idea that a person is looking for a solution to a very specific problem which comes out of the original inquiry process. STEAM is an academic term in the field of education. The University of San Diego and Concordia University offer a college degree with a STEAM focus.

Basically STEAM is a framework for teaching or R&D, which is customizable and functional, thence the “fun” in functional. As a typical example, if STEM represents a normal cell phone communication tower looking like a steel truss or concrete column, STEAM will be an artificial green tree with all devices hided, but still with all cell phone communication functions. This e-book series presents the recent evolutionary progress in STEAM with many innovative chapters contributed by academic and professional experts.